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# DIET AND DIET SELECTION OF THE DESERT TORTOISE (*GOPHERUS AGASSIZII*) IN THE NORTHEAST MOJAVE DESERT

Submitted by

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## ABSTRACT OF THESIS

## DIET AND DIET SELECTION OF THE DESERT TORTOISE (*GOPHERUS AGASSIZII*) IN THE NORTHEAST MOJAVE DESERT

Diet and diet selection of desert tortoises were studied for four years (1989 - 1992) at the City Creek Site, Washington County, Utah; and the Littlefield Site, Mohave County, Arizona. The focus of the research was to determine diet, test the hypothesis that desert tortoises feed on plant species at random with respect to their availability in the habitat, and to consider the mechanisms for diet selection, if it occurred. Radio-telemetered desert tortoises (N = 7 - 17 per site among years) were closely observed in their habitats on 1.6 $km^2$ study plots. Habitat characteristics were quantified including: biomass production and frequency of annual plant species, and cover of perennial plant species. Diets were quantified by the total number of bites of each plant species eaten by tortoises. Diet selection occurs when an animal eats a species in a greater or lesser frequency than would be expected at random based on the availability of the plants. Plants may be preferred, avoided, or eaten at random with respect to availability. Frequency data compared the use of plant species in the diets of desert tortoises versus the relative availability of each plant species in tortoise habitats. Diet selection was analyzed using the alpha preference matrix statistic and Hotelling's t-test. *Post hoc* analyses for diet selection of individual species relative to each other were analyzed using a multiple t-test with corrected critical values using Bonferonni's Inequality. Desert tortoises ate 79 plant species at the City Creek Site, and 32 species at the Littlefield Site. Tortoises sampled about 50 percent of the species available at each site. Although a relatively large number of species were sampled by tortoises, only

three to five species made up the bulk of diets. Annual grasses were more prevalent in the diet in years when their biomass production was elevated. Tortoises ate more forbs than grasses early in the spring and more grasses than forbs later in the spring. Exotic plant species as well as native plant species were important foods. However, exotic plant species were less prevalent in the diet as biomass production of all annual species increased. Exotic plant species common in the diet included: *Bromus rubens*, *B. tectorum*, *Erodium cicutarium*, and *Schismus barbatus*. Native annual species that were important in diets included: *Plantago patagonica*, *P. insularis*, *Stephanomeria exigua*, and *Descurainia pinnata*. Statistically significant evidence of diet selection occurred at the City Creek Site every year that it was tested. Selection also occurred in 1990 and 1992, but not in 1991 at the Littlefield Site. Among those species analyzed for selection, individual species were selected over others. However, among those species tested, no single species was consistently either avoided or preferred in all years. There appears to be a lack of pattern in diet selection. It was hypothesized that certain species would be selected consistently, if selection occurred. Selection also was not dependent upon biomass production of species or dispersion of species. There were several species of plants that were consistently avoided, but were too rare to be analyzed (e.g., woody perennial plants, cactus, and a few annual species). Based on their prevalence in the habitat, but absence in diets, those species were mostly avoided. There are probably multiple reasons why some plants were avoided including: the presence of secondary compounds, morphology of the plant species (inaccessible to tortoises), and relative abundance (rarity) of those species.

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# DIET AND DIET SELECTION OF THE DESERT TORTOISE (*GOPHERUS AGASSIZII*) IN THE NORTHEASTERN MOJAVE DESERT

## INTRODUCTION

Diet may be defined as the totality of food resources eaten by an individual, population, or species. Our knowledge of diet is the basis on which we can determine nutritional needs of desert tortoises. Diet can be described by sacrificing organisms and examining their gut contents, by analyzing fecal material, and by observation in the field (Korschgen 1980). Methods that included sacrificing tortoises (Ortenburger and Ortenburger 1927) have been replaced by non-destructive methods of assessing diet. Since the first comprehensive study of desert tortoise ecology (Woodbury and Hardy 1948), several research projects have investigated tortoise diets using non-destructive techniques. Microhistological analysis of fecal material has been used to identify items in the diets as well as to determine relative use of plants in the diet (Hansen et al. 1976, this Thesis, Van Devender et al. 1993).

Feeding observations of wild desert tortoises have been described in southern Nevada (Burge and Bradley 1976) and in west-central Nevada (Nagy and Medica 1986), in California (Marlow 1979, Luckenbach 1982), and in northwest Arizona (Hohman and Ohmart 1980). There have been a number of studies that made anecdotal descriptions of the diets of tortoises in parts of the northeastern Mojave Desert including: the Beaver Dam Slope, Utah (Woodbury and Hardy 1948, Hansen et al 1976); the Pakoon Basin, Arizona (Hansen et al 1976); and the Ivanpah Valley, California (Turner et al. 1984, Avery 1992). The purpose of this paper is to describe the diet of desert tortoises in the northeast Mojave Desert . To describe diet and determine diet selection I asked two questions:

Question 1: Do tortoises preferentially select particular food species among those available within the habitat during the spring feeding season?

Question 2: Do tortoises preferentially select particular food species among those available along travel routes on a daily basis?

Knowledge of diet is fundamental to our understanding of the growth and health of individual animals and populations (Robbins 1983). Diet information for herbivores, such as the desert tortoise, is important because it helps to define the relative abundance of various plant species in animal diets. Only then is it possible to investigate the relationships between quantity of plant species eaten and the nutritional quality of the plant species that tortoises eat. Diet information for the desert tortoise is particularly useful because it helps us understand the

special challenge of acquiring appropriate nutrition for herbivorous ectotherms (Nagy 1977, Voorhees 1981, Troyer 1982, Christian et al. 1984, Bjorndahl 1987, Pough 1973, Zimmerman and Tracy 1989). As we learn about the nutritional quality of tortoise food plants, it is feasible to experiment with diets under controlled conditions and equate diet quantity and quality with the condition of wild animals (Bjorndahl 1987). Ultimately, experimentation and observation can be used to understand the relationship between diet quality and the growth, health, and fecundity of individual animals and populations. These data in turn can be used to formulate and test hypotheses pertinent to current theoretical questions about diet selection, habitat quality and carrying capacity of habitats. After describing the diets of desert tortoises at two sites in the northeast Mojave Desert, I test the null hypothesis that, "*desert tortoises eat plant species at random with respect to plant abundance in the habitats of the tortoises.* "

Knowledge of diet selection has important theoretical considerations. Whether desert tortoises prefer, avoid or eat plants at random with respect to availability can provide empirical data to support or refute theories of diet and foraging optimality (Emlen 1966, McArthur and Pianka 1966, Schoener 1971, Stephens and Krebs 1986), nutritional wisdom (Westoby 1974), digestive efficiency and energy assimilation (Nagy and Medica 1986, and Bjorndahl 1987) and, functional response (Spalinger and Hobbs 1992, Gross et al. 1993). Does diet selection occur for specific plant species or qualities of plants? If diet selection occurs, what are the common characteristics of the plants that are selected (e.g., energy, minerals, or water)? If tortoises have the ability to select plant species of highest quality, then they demonstrate a form of nutritional wisdom. Furthermore, if tortoises consistently prefer plants with the greatest

nutritional quality, this implies that they optimize their diets on the basis of nutrition thus corroborating theories about optimality of diets.

Predictions can be made about the diets and selection of desert tortoises based on characteristics of their habitats. Ideas about animal feeding behavior in relation to food availability are considered in hypotheses about optimality of feeding (Emlen 1966, MacArthur and Pianka 1966, Schoener 1971). Optimal foraging hypotheses predict organisms will be more selective when resources are plentiful. Conversely, organisms are predicted to be generalists (eating whatever is available), when resources are rare.

The Mojave Desert is notoriously variable, both temporally and spatially, in the amount of rainfall available for plants to grow (Beatley 1974, Brown 1982). To persist in this variable environment, many desert herbivores feed on a wide range of plant species, plant growth forms, and portions of plants (Noy-Meir 1974). Shifts in the diet often reflect the availability of food; however, subtle preferences may be based on physiological needs. This has been described as flexible or facultative selectivity (Noy Meir 1974, Glasser 1984, Cayot 1987).

For conservation actions, diet and diet selection can be used to compare resource use by desert tortoises among locations and to define the response of animals to fluctuating environmental conditions. This type of information is fundamental to sound habitat management (Cooperrider 1986), because the desert tortoise is listed by the federal government as a species threatened with extinction in the Mojave Desert (Federal Register 1990). Competition for forage with domestic livestock, and invasion of exotic plant species are listed among the possible causes of population declines. The information provided here can

be used to compare the diet of desert tortoises with that of livestock using the same habitats to determine the degree of competition for food resources (Spang et al. 1988). Also, the data provide a measure of the relative abundandce of exotic plant species in the diets of desert tortoises. These data contribute to the body of knowledge needed for the recovery of the desert tortoise.

# METHODS

## *Study Sites*

The northeastern Mojave Desert is a vast area that covers parts of southwestern Utah, northwestern Arizona, southern Nevada, and easternmost California (Brussard et al. 1993). Study sites were located in the northeastern extent of the Mojave desertscrub biome (Turner 1982), which is also the northeastern limit of the desert tortoise geographic distribution (Patterson 1982, Brussard et al. 1993). This study was conducted at: the City Creek Site in Washington County, Utah; and the Littlefield Site in Mohave County, Arizona (Fig. 1).

City Creek Site(CC). The City Creek Site is north of St. George, Utah (Washington 7.5' Quadrangle R16W, T42S, E1/2 section 12 and R15W, T42S, W1/2 section 7; USGS 1986a)(Coffeen et al. 1989), and is part of the Upper Virgin River Recovery Unit for the federally listed desert tortoise population (Fig. 2). Climate data were gathered from the St. George, Utah, weather station, 4 km south of the City Creek Site (NOAA 1991). Habitat patches were divided into subhabitats. Subhabitats were mapped using aerial photographs and topographic maps, and verified from observations at the sites. Physiographic and vegetative information from both sites was digitized and entered into a Geographic Information System (GIS) using a vector based, map overlay statistical system (MOSS) modified for the Bureau of Land Management in their

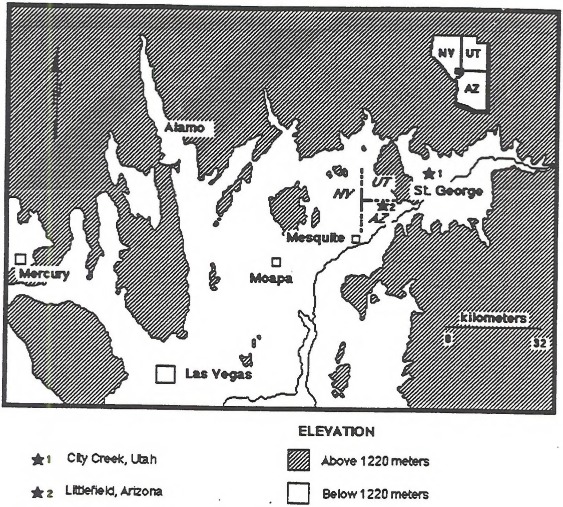

Figure 1. Study areas in the northeastern Mojave Desert.

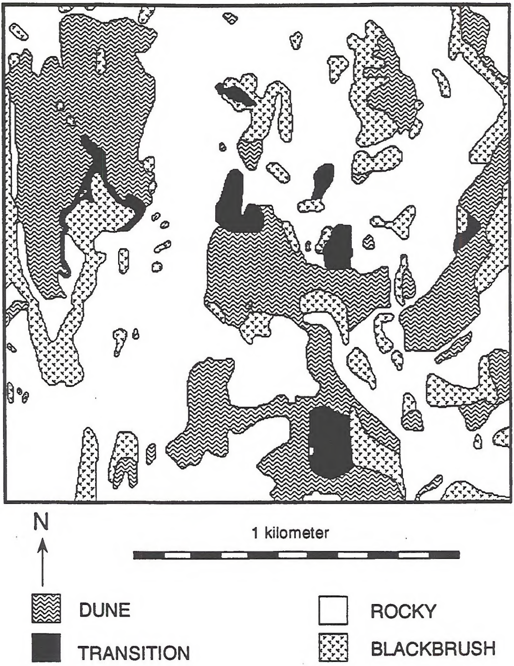

Figure 2. Habitat map of the City Creek Site, Utah (after Coffeen et al. 1989).

Land Information System. The City Creek Site subhabitats were analyzed for area cover using GIS data.

Tortoises from the Upper Virgin River Recovery Unit are apparently isolated from all other populations of the Mojave Desert (Bury et al. *in press*). The elevational range at the City Creek Site is 975 m to 1067 m (3200 ft to 3500 ft). Slope and exposure are extremely variable. Red Navajo sandstone is the predominate substrate and has a basalt cap in some places. Desert tortoises in the Upper Virgin River Recovery Unit occur in localized areas of dense colonies. The desert tortoise population at the City Creek Site was estimated. In 1988, 230 tortoises (all marked) were found on the 2.59 sq. km City Creek Site (R. Fridell, Utah Division of Wildlife Resources, *pers comm.*).

The Littlefield Site (LF site). The Littlefield Site is located 3.5 km north of the community of Littlefield, Arizona (Grand Canyon Quadrangle; T41N, R15W, S27 (USGS, 1986b)) (Fig. 3).The elevational range is 597 - 622 m (1958 - 2040 ft.). Climate data were gathered from Beaver Dam, Arizona, 3.2 km southwest of the Littlefield Site(NOAA 1991). Hohman and Ohmart (1980) earlier studied the ecology of desert tortoises at this site. The Littlefield Site has a moderately low density tortoise population of about 50 tortoises per 2.59 sq. km (Duck and Schipper 1989, Rourke et al. 1993.). To determine percentages of availability of habitat patches a habitat map of the Littlefield Site was photocopied onto acetate (see section under the City Creek Site for methods). The acetate map was cut into pieces representing each subhabitat and the pieces were weighed to infer the total area represented by each subhabitat.

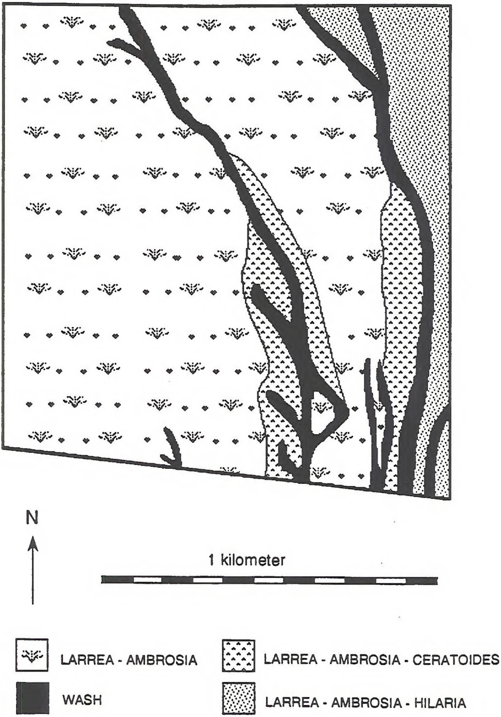

Figure 3. Habitat map of the Littlefield Site, Arizona.

### *Vegetation*

Frequency and aboveground biomass production was measured for spring annual plants in 1989 - 1992 at the City Creek Site, and in 1990 - 1992 at the Littlefield Site. Also, cover and density were measured for spring annuals at the City Creek Site in 1989 - 1990, and at the Littlefield Site in 1990. Perennials were sampled at both sites in 1990. Plant species were identified using Welsh *et al.* (1987), Jaeger (1979), and by comparison with herbarium specimens at the US Department of the Interior, Bureau of Land Management (BLM), Arizona Strip District, Shivwits Resource Area.

Perennial Vegetation. Perennial cover was estimated using the line-intercept method (Canfield 1941) on 50 m long transects. The 50 m transects at each site were distributed in a stratified-random design among each of four subhabitats at each study site. Each site was divided by a grid at 1/10 mile intervals. Transect locations were chosen from among grid-points and mid-points between each grid-point. Then random transect locations were chosen using a hand held calculator. A series of locations was chosen for each subhabitat type. The number of transects was based on the number of annual plant quadrats required for adequate sampling (see subsequent section).

The City Creek Site was sampled with 39 transects, and the Littlefield Site was sampled with 49 transects. Minimum bare ground (ground devoid of perennial cover) was estimated by subtracting total perennial cover on each transect from 50 meters and averaging the values for all transects within subhabitat types. Transect ends were permanently marked with iron stakes and numbered with aluminum tags.

Annual Vegetation. Annual vegetation was measured on 1 $m^2$ quadrats that occurred at 10 m intervals along the line-intercept transects that were conducted for perennial plants. Frequency and aboveground biomass production were measured for all species of annual plants that were located. Each quadrat was treated as a random sample point. The quadrats were measured with a collapsible wooden frame. Aboveground production of the dry biomass of each species of spring annuals was estimated from air-dried samples from each quadrat and weighed to the nearest milligram. Adequacy of sampling for annual species was determined by graphing the cumulative variance in mean biomass versus the total mean biomass for all species on 1 $m^2$ quadrats. This method was employed during a pilot study, in 1989, to provide a range of values that was useful in subsequent years. Sampling was considered adequate if the slope did not vary from zero on five consecutive transect points. In addition, the density, frequency and cover were calculated for each species in 1989 and 1990. Among year and among site comparisons of aboveground dry biomass production were made using one-way analysis of variance. Fisher's Protected LSD was used to test for among year differences in biomass production within sites.

Between 35 - 40 quadrats were completed within each subhabitat type at each site during the study. In 1989, annual vegetation transects were conducted between 26 April - 4 June at the City Creek Site. The Littlefield Site was not sampled in 1989. After 1989, vegetation transects were completed within a three week time frame to ensure compatibility of the data. In 1990, vegetation transects were measured at the City Creek Site and the Littlefield Site concurrently. In 1991, transects were completed between 9 - 31 May at the City

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COLORADO STATE UNIVERSITY

SEPTEMBER 21, 1993

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY TODD C. ESQUE ENTITLED, DIET AND DIET SELECTION OF THE DESERT TORTOISE (*GOPHERUS AGASSIZII*) IN THE NORTHEAST MOJAVE DESERT, BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

R. Bruce Bury

Phillip L. Chapman

C. Richard Tracy
Adviser

Joan M Hube
Department Head

Creek Site, and 10 - 28 May at the Littlefield Site. In 1992, transects were completed 3 May - 22 May. Summer vegetation was not quantified at either study site. However, voucher specimens for summer annuals were collected at each site.

Data were collected on biomass production, and frequency of annual plant species in all years. Density and cover of annual plant species were collected in 1990 and 1991. Biomass production of annuals was estimated for individual plant species, individual subhabitat types, and total average plant biomass by site among years. When total biomass, frequency, or density values were reduced by species or by year, the data were weighted to account for unequal representation of subhabitats (by area):

$$\text{Weighted Value} = ((A * B) / C) * D; \qquad \text{(Eq. 1)}$$

where, A is the estimated biomass, B is the area of the subhabitat in which A occurs, C is the total area of the study site, and D is the number of subhabitat types. Values were also corrected for unequal sampling by eliminating excess transects or choosing quadrat totals from among the sample estimates at random and duplicating those values to standardize sample numbers.

Dispersion and Biomass Production of Annual Plants. The distribution of plants or their differential appearance could affect what plants are eaten by tortoises. Selection of plant species by tortoises was assessed relative to dispersion and biomass of plant species in the habitat. Dispersion of annual

plant species was determined using the variance to mean ratio (Greig-Smith 1983):

$$\text{Dispersion} = (A / B) * (C - 1); \qquad \text{(Eq. 2)}$$

where A is the variance, B is the mean density per species, and C is the number of transects. Dispersion of plant species and available biomass of species were compared with diet selection values using regressions to understand the role of these variables in diet selection.

Trends in Plant Biomass from BLM Data (1980-1991). Plant biomass production of desert annuals on the Beaver Dam Slope, Utah, was monitored by BLM - Utah, Dixie Resource Area (1980-1992 - *Unpublished data*). These data were collected from the upper bajada of Utah Hill and the Beaver Dam Mountains proper in Washington County, Utah (on the same major physiographic feature as the Littlefield Site). Nine permanent plots were marked with metal fence posts at random locations. After each post was located, the person taking samples walked 20 paces in a randomly selected direction and placed a sampling quadrat. This procedure was repeated in series 10 times resulting in a transect. Three such transects were completed from among the nine total and rotated annually each year for a total of 30 sampling plots. Each quadrat was treated as a random quadrat. Sampling quadrats were 1 $m^2$. All annual vegetation was clipped within the hoop. Plant specimens were then weighed fresh, oven-dried (35-40° C) and subsequently weighed to determine dry biomass production. Data were displayed as the mean of means for each year.

### *Tortoise Observations*

Radio Telemetry. Repeated observations of desert tortoises were aided through the use of radio telemetry. The radio transmitter packages consisted of a two-stage transmitter, a 3 volt-AA battery, and an antenna (~25 cm long). Radio packages weighed about 30 g. Epoxy glue was used to attach the radios to each tortoise. Each radio was attached centrally to the first costal scute on the left or right side of the carapace. The radio antenna was also glued with epoxy to the carapace of each tortoise. Masking tape was placed on sutures between scutes wherever the glue was applied. Thus, the glue would not irritate sensitive areas of tissue growth, or damage the tortoises shell on removal of the radio, and to allow for growth of the animals. We used hand-held radio receivers with a two-element yagi antennae to receive transmissions. Average range of each transmitter was ~500 m, depending on the terrain where tortoises were located, and also on the age of the battery.

Observation Periods. We observed foraging tortoises from April through June in four years (1989 - 1992) at the City Creek Site; and three years (1990 - 1992) at the Littlefield Site (App. I). The total number of tortoises observed each year at each site was variable (App. I). Daily behavioral observations began at about 0600h MST but varied according to seasonal tortoise activity patterns; observations continued through the day. We located tortoises before they emerged from their overnight cover sites whenever possible, and we observed tortoises from close distances (5 - 20 m) throughout the day. Binoculars were used to identify what food items were consumed by tortoises. We recorded detailed notes on a microcassette recorder including: time and location each tortoise emerged from and returned to cover sites; beginning and ending points;

distance traveled during observation; number and size of feeding patches visited; items ingested; number of bites taken of each food item; and interactions with other animals. After the observation period, travel routes were recorded on data sheets. Recorded were: the configuration of the daily movements; and description of cover sites. Later in the day, tape recordings were transcribed onto feeding observation data sheets (App. II) .

### *Diet and Diet Selection of Desert Tortoises*

Diet *selection* describes patterns in feeding behaviors of animals. Diet selection can be categorized as preference, avoidance, or random use. Selection occurs when animals feed on particular food items to a greater or lesser extent (preference or avoidance, respectively) than would be expected if animals simply ate items in the same frequencies with which the plants are available in the habitat. Random use of food resources occurs in the absence of statistical preference or avoidance.

To analyze diet selection, I tested the null hypothesis that:

> $H_0$: tortoises feed on each species of plant with the same frequency with which food species are found in the habitat.

The alternative hypothesis is that tortoises prefer or avoid certain items in their diets with respect to availability. Knowing whether or not tortoises select their diets under different environmental conditions (e.g. among years of different

plant production or availability of some species) helps determine the mechanistic underpinnings of feeding behavior in desert tortoises.

Analyzing Desert Tortoise Diets. Diets of tortoises were determined by counting the total number of bites for each species of plant eaten. One bite was counted for each single cropping motion (Gross et al. 1993) made as a tortoise opened and closed its mandibles on a potential food item. Relative proportions of plant species in tortoise diets, and the number of species in diets, were compared among years and at the two study sites. Diversity of diets was compared to the biomass production and number of plant species available to tortoises in given years. The diversity of plants available in the habitat was determined from the number of species that occurred during sampling of plant biomass.

Analyzing Diet Selection in Desert Tortoises. Diet selection was measured at two spatial scales. First, diet selection was determined by comparing the frequency in which each food species was eaten (*Use*) with the frequency of plants found at random in the habitat of desert tortoises (*Availability*). Diet selection was measured within the habitat used by the two sample populations of tortoises during the entire spring feeding season. Then diet selection was compared to the availability of plant species within feeding patches, along daily feeding routes of tortoises.

Diet Selection Among Years and Within Years at Two Sites. Diet selection was compared *among years* by including food species that were common to all years and comprised at least 1% of the relative number of bites and at least 1% of plant availability in all years. Within *years* comparisons included all food

species that occurred within a given year on at least 1% of the vegetation transects used to determine availability of plants and at least 1% of the relative number of bites eaten by desert tortoises in that year. Plant species that were too rare to be included in statistical analyses are discussed separately.

Spatial Sampling Design. The frequency with which each plant species was eaten by a tortoise within 1 $m^2$ feeding patches (referred to as *Use*) was tallied at the end of each observation, and totals for all observations within each year were summed for spring feeding periods (ca. March through June) to measure use (Fig. 4). Those data were then compared to the frequency of occurrence for plant species occurring on the study sites in the same year (Fig. 4). Availability was measured on stratified-random transects (1 $m^2$). Each transect consisted of 5 quadrats spaced 10 m apart. All quadrats were summarized as totally random quadrats for analysis.

Pooling Species for Statistical Analysis. Some plant species were pooled due to taxonomic and morphological similarities. *Bromus rubens* and *B. tectorum* were combined into *Bromus spp.*; *Cryptantha angustifolia*, *C. nevadensis*, and *C. virginensis* were lumped as *Cryptantha spp.*; all *Gilia* species were tallied as *Gilia spp.*; and *Plantago insularis* and *P. patagonica* were combined to form *Plantago spp.*

Statistical Analysis of Diet Selection. Diet selection was determined by comparing the *availability* of plant species in the habitat of the tortoises to the *use* of plant species during observations of the tortoises. Selection was

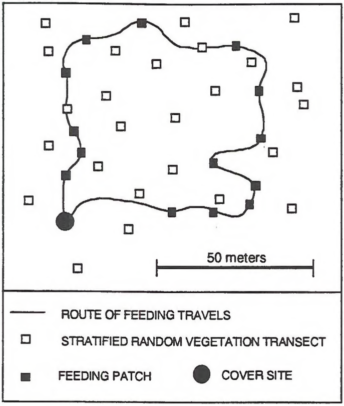


Figure 4. Conceptualization of statistical design for sampling diet selection.

analyzed using the alpha-vector ($\alpha$-vector) preference metric (Chesson 1983, Crist and MacMahon 1992). The $\alpha$-vector preference metric uses a vector of a preference values of the $i$ th animal and for the $j$ th plant species of interest. Eacn $\alpha$ value in the vector represents the $j$ th plant species for the $i$ th individual animal. The alpha preference value is calculated in Equation 3:

$$\alpha_{ij} = ( \text{Use}_{ij} / \text{Availability}_{ij} ) / \sum_{j=1}^{N} ( \text{Use}_{ij} / \text{Availability}_{ij} ); \quad \text{(Eq. 3)},$$

where *Use* is the frequency of feeding patches in which a tortoise was observed feeding on a plant species, and *Availability* is the frequency of occurrence of those plant species in $m^2$ patches across the habitat of the tortoises.

Alpha vectors for each plant species were entered into a matrix of plant species by individual animals. Analyses were performed on that part of the matrix in which plant species occurred in at least 1% of the vegetation transects and at least 1% of the relative number of bites at a given site in a given year.

Data in the matrices were arcsine - square root transformed to normalize distributions. Mean alpha preference values for each plant species were compared statistically using Hotelling's $T^2$- test (Systat 1992).
Significant selection occurs if the null hypothesis is rejected. The null hypothesis states that mean alpha preference values are equal among plant species:

$$H_0: x_1 = x_2 = x_3 = x_4 = \ldots x_N$$

where $x_i$ was the mean alpha preference value for each species in the analysis.

If the null hypothesis was rejected, then diet selection occurred and, at least one species in the analysis may have been either preferred or avoided statistically significantly in relation to other species in the analysis. Selection trends were illustrated by graphing the alpha preference values for each plant species in relation to the total mean alpha value for all species in the analysis ($\mu$). Estimation of $\mu$ was achieved by summing the mean alpha values for all plant species in the analysis and dividing that sum by the number of plant species in the analysis. Generally, a species was considered to be preferred if the mean alpha value was greater than $\mu$ and its standard error did not intersect $\mu$. A species was considered to be *avoided*, if the mean alpha value was less than $\mu$ and the standard error did not intersect $\mu$. Species that were not either avoided or preferred with respect to their availability are discussed as random with respect to their role in diet selection. However, those species were not considered to have been fed upon at random statistically with respect to their availability. This comparison illustrated possible trends toward avoidance, or preference. Finally, mean alpha preference values were compared sequentially for all combinations of pairs of species with paired, two-tailed t-tests, to test for significance of selection among all species. In the t-tests, critical values were corrected using Bonferonni's Inequality which is a very conservative test that controls for experiment-wise error (Equation 4):

$$\text{Bonferonni's Inequality} = (A) / (N * N-1) / 2, \qquad \text{(Eq. 4)},$$

where A is the arbitrarily chosen critical value (in these analyses the critical value was equal to 0.05), and N is the number of plant species included in the analysis.

Diet Selection Along Daily Feeding Routes. There were two primary questions considered in relation to the feeding routes of tortoises.

Question 1: Do tortoises forage along a route which has plants that are different from the plants that would be found on a random route through the habitat?

Question 2: Do tortoises preferentially select particular food species from among all those plant species available within feeding patches?

During feeding observations in 1992, we marked individual feeding patches (1 $m^2$) using pin flags. These pin flags not only marked individual feeding patches, but they also indicated travel patterns of tortoises. The *availability* of plants along feeding routes was compared to the *availability* of plant species on random quadrats throughout the study site. I analyzed diet selection of plants along feeding routes by comparing the frequency of plants that were eaten in feeding patches (Fig. 4) with the frequencies of all plants available in the feeding patches (Fig. 4). A 1$m^2$ quadrat was centered on the pin flag at each feeding patch and edges of the square quadrat were always aligned along a north -south vector.

Selection was compared at two scales. First, the frequency with which each food species was eaten on feeding patches was compared to the frequency of availability of plants within the entire habitat on random quadrats. Then, the frequencies with which each plant species was eaten in all observations was

compared to the frequencies of all plant species found in feeding patches during the observations. The frequency with which tortoises ate plant species, and the frequency of plant species availability, were compared using simple regressions and 95% confidence intervals. Species occurring exactly on the regression lines, or inside the confidence limits were considered to have been eaten at random with respect to their availability. This definition of *random use* is not considered in the literal statistical sense of randomness, but relative to the other plant species that were eaten that occurred outside the confidence intervals. Species that occurred above the regression line and outside the confidence intervals were considered to be preferred. Plant species below the regression lines and below the lower confidence interval were avoided.

# RESULTS

## *Weather and Climate*

Mean annual precipitation at the St. George weather station (located 4 km south of the City Creek Site) is 203.0 ± 62.2 (SD) mm over a 63 year period (1928 - 1991). Maximum and minimum annual precipitation was 365.3 mm (in 1941) and 90.9 mm (in 1956), respectively (App. III A). Maximum monthly precipitation was in January (highest recorded value - 113.28 mm in 1980). Values of zero precipitation have occurred in every month at some time during the sixty-four years; however, June has the lowest long-term average monthly precipitation (5.1 mm).

Weather data were analyzed by *water year*. A water year is a way of describing biologically meaningful precipitation patterns throughout the year. The water year begins in September in the northeast Mojave Desert because fall and winter rainfall are important to the bloom of perennial plants (usually in the spring) and to spring annual plants. Precipitation in the 1989-90 and 1990-91 water years was below the long-term average (59 and 62% below average respectively). Precipitation in the 1989-90 and 1990-91 water years also fell at, or below, the lower limit of the standard deviation of the means for those

months. This study occurred during the last three years of a drought that encompassed most of the southwestern United States.

Mean annual precipitation at the Beaver Dam, Arizona weather station was 185.4±59.4 (SD) mm and represents a thirty-six year time span (1956 - 1992). Maximum and minimum annual precipitation occurred in 1978 (363.7 mm) and 1968 (59.4 mm), respectively (App. III B). The maximum monthly precipitation usually occurs in March. Like St. George, the minimum monthly precipitation is expected in June. Zero rainfall has occurred in all months. The Littlefield Site received below average precipitation for the 1988-89, 1989-90, and 1991-92 water years. However, rainfall was at least 90% of normal in all of those years.

### *Subhabitats and Vegetation*

The City Creek Site. The vegetation at the City Creek Site is Mojave desertscrub (Brown 1982) with Great Basin desertscrub and Colorado Plateau species co-occurring. Dominant perennial plant species include: Mormon tea (*Ephedra nevadensis*), blackbrush (*Coleogyne ramosissima*), sand sage (*Artemesia filifolia*), and creosote bush (*Larrea tridentata*). The CC site has four discrete subhabitat types: Dune, Transition, Blackbrush, and Rocky subhabitats. Stratifications were based upon vegetation and edaphic characteristics (*i.e.* dominant perennial species, soil particle size, and composition of soils). The total area of the City Creek Site study site was 271.6 ha. Subhabitats were unequally represented: Dune subhabitat 67.3 ha; Rocky subhabitat 140.7 ha, Transition subhabitat 15.3 ha and Blackbrush 48.3 ha. Soils in Dune subhabitat are fine wind-blown sands that contain less than 8% clay. The perennial vegetation association in Dune subhabitat was *Ephedra nevadensis* ,

*Artemesia filifolia and Prunus fasciculatum*. Transition subhabitat was dominated by *E. nevadensis, Coleogyne ramosissima, and Gutierrezia spp.* and *Hymenoclea salsola*. Transition subhabitat soils usually supported a soil crust formed by a cryptogamic community. Cryptogamic communities include: lichens, mosses, and cyanobacteria (Harper and Pendleton 1993). Cryptogamic communities occurred in, and on, the soil surface. Blackbrush subhabitat had a vegetation association of: *Coleogyne ramosissima, E. nevadensis-, and Krameria parvifolia* with outlier species from Rocky and Transition subhabitats and poorly developed rocky soils. Rocky subhabitat had little or no soils (mostly expansive slabs of Navajo sandstone). The perennial association in Rocky subhabitat was *C. ramosissima, Ephedra nevadensis*, and *Eriogonum fasciculatum* .

There were 152 species of plants identified at the City Creek Site (App. IVA). Perennial plants accounted for most of the plant species diversity, followed by winter annual species, and then summer annuals (Table 1). Biomass production and frequency values for diet plant species were weighted to compensate for unequal representation of subhabitats on the study plots for some analyses (Appendices V A, B, and VI A - F, respectively).

Total aboveground biomass of annual plant species was lowest in 1990 and greatest in 1992 (Table 2, Fig. 3, App. VII) and was significantly different among all years at the Littlefield Site. Production was generally lowest in Rocky subhabitat and always greatest in Transition subhabitat (Table 3). Transition subhabitat had significantly greater biomass production of annual species than other subhabitat types, as well as, the greatest number of species in all years (App. VIII A - C, Table 3, and App. VIA - C, respectively). Rocky subhabitat had

significantly less biomass production than all other subhabitats in 1992 (App. VIII A). Biomass production was not significantly different among years in Rocky subhabitat in any year (Appendix IX A). Biomass production in Dune, Blackbrush and Transition subhabitats was significantly different in 1992 from 1990 and 1991 (Appendix IX A). *Bromus spp.*, and *Erodium cicutarium* (both introduced species) were among the top five

species for greatest biomass production in all years (App. X A). Two large, native species of Brassicaceae, *Descurainia pinnata* and *Streptanthella longirostris*, were among the top five species with respect to biomass production in years of greatest biomass production (App. X A). Blackbrush subhabitat had the greatest year-to-year variation in species diversity (range = 2 - 35 species), and Dune subhabitat had the least variation in number of species present (range = 8 - 19 species) (App. X A). Rocky and Dune subhabitats generally had the least number of species represented on the site. Xeroriparian areas (intermittent, usually dry watercourses) occurred in every subhabitat type to varying degrees, and in some years these areas inflated species diversity for subhabitats.

Table 1. Plant species represented by the number of species per growth form at the City Creek and Littlefield Sites. Plant lists consisted of all plant species located during studies from 1989 - 1993.

| | **CITY CREEK SITE** | **LITTLEFIELD SITE** |
|---|---|---|
| GROWTH FORM | NUMBER OF SPECIES | NUMBER OF SPECIES |
| PERENNIAL | 86 | 33 |
| *Woody shrubs and trees* | 38 | 14 |
| *Forbs* * | 32 | 8 |
| *Grass* | 10 | 6 |
| *Succulent* ** | 6 | 5 |
| WINTER ANNUAL | 64 | 32 |
| *Forb* | 59 | 29 |
| *Grass* | 5 | 3 |
| SUMMER ANNUAL | 2 | 1 |
| **Total Number** | 152 | 66 |

* Including ferns

** Including stem succulents

Table 2. Total mean aboveground dry biomass production (kg/ha) estimates for annual plants at the City Creek and Littlefield Sites in 1990 - 1992. Values were weighted to standardize differential biomass production among subhabitat types (Eq. 1).

| Year | Number of Quadrats | Weighted Mean Biomass (kg/ha) | Standard Deviation |
|---|---|---|---|
| ***CITY CREEK SITE*** | | | |
| 1990 | 90 | 4.20 | 18.34 |
| *1991 | 165 | 30.68 | 71.56 |
| 1992 | 150 | 119.52 | 144.83 |
| 1993 | 162 | 131.03 | 151.28 |
| ***LITTLEFIELD SITE*** | | | |
| 1990 | 160 | 24.25 | 41.22 |
| *1991 | 148 | 75.80 | 112.52 |
| 1992 | 176 | 400.84 | 661.26 |
| 1993 | 150 | 1128.15 | 3149.38 |

*Data for May of 1991

Table 3. Mean spring aboveground dry biomass production (kg/ha) estimates for annual plants among subhabitats* at the City Creek and Littlefield Sites in 1989 - 1992.

*CITY CREEK SITE*

| | **TRANSITION** | | | **BLACKBRUSH** | | | **ROCKY** | | | **DUNE** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Biomass Production ** | SD | N | Biomass Production ** | SD | N | Biomass Production ** | SD | N | Biomass Production ** | SD | N |
| 1989 | 23.0 | 42.6 | 36 | 8.1 | 11.0 | 38 | 5.2 | 7.9 | 39 | 2.4 | 5.3 | 41 |
| 1990 | 16.2 | 16.5 | 30 | 4.7 | 5.8 | 20 | 4.6 | 17.6 | 20 | 0.6 | 0.2 | 20 |
| 1991 *** | 118.6 | 115.9 | 40 | 35.4 | 87.7 | 40 | 11.2 | 36.4 | 22 | 47.7 | 92.5 | 43 |
| 1992 | 484.2 | 363.0 | 34 | 126.3 | 176.6 | 35 | 11.8 | 25.2 | 15 | 195.6 | 210.8 | 35 |

*LITTLEFIELD SITE*

| | **LA** | | | **LAC** | | | **LAH** | | | **WASH** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Biomass Production ** | SD | N | Biomass Production ** | SD | N | Biomass Production ** | SD | N | Biomass Production ** | SD | N |
| 1990 | 26.0 | 26.7 | 40 | 15.3 | 11.7 | 20 | 45.7 | 28.0 | 26 | 39.5 | 34.7 | 40 |
| 1991 | 73.9 | 66.2 | 40 | 41 | 42.6 | 35 | 109.8 | 80.2 | 35 | 56.0 | 91.3 | 38 |
| 1992 | 492.3 | 382.7 | 28 | 311.3 | 385.8 | 36 | 388.0 | 291.8 | 44 | 787.1 | 722.8 | 39 |

* Values were not corrected or weighted because a comparison among years is more accurate when not manipulated.

** Mean Biomass Production measured in Kg/ha.

*** Data for May of 1991

Perennial plant cover varied greatly among subhabitats. The greatest total mean plant cover occurred in Dune subhabitat. Rocky subhabitat had the least mean cover and variance and had significantly less cover than Transition or Dune subhabitats (App. XI A). Blackbrush subhabitat also had significantly less cover than Dune subhabitat. Transition and Dune subhabitat had the greatest mean perennial plant cover and also had the greatest variance in mean perennial cover (Table 4). *Ephedra nevadensis* was included among the top two perennial plant species in all subhabitats (App. XII).

Littlefield Site. This site was located on a lower bajada sloping gently southward toward the Virgin River less than 1.5 km away. Topography included flat areas separated by shallow washes or deeply cut arroyos (occasionally as deep as 6 m). Soils are comprised of alluvial deposits with little organic matter. The Littlefield Site plot is characterized as Mojave desertscrub (Brown 1982). *Larrea tridentata* and *Ambrosia dumosa* are dominant woody perennials, while *Ceratoides lanata* and *Lycium spp.* were locally abundant in flat areas. Cacti such as *Ferocactus acanthodes*, *Neolloydia sp.* and *Opuntia basilaris* were uncommon. *Hilaria rigida* was the most abundant perennial grass.

I stratified the site into four subhabitat types. Wash subhabitat constituted the deep cuts in the homogeneous flat areas with largely calcareous soils. The perennial plant association in Wash subhabitat was: *Baccharis sergiloides, L. tridentata, H. salsola, and A. dumosa*. LA subhabitat was dominated solely by *L. tridentata, And A. dumosa*. LAC subhabitat was an association of *L. tridentata, A. dumosa , and C. lanata*. LAH subhabitat was an association of: *L. tridentata, A. dumosa , and H. rigida* . The total area of the Littlefield Site was 273.5 ha and

Table 4. Descriptive statistics for perennial plants derived from vegetation transects at the City Creek and Littlefield Sites in 1990.

**CITY CREEK SITE**

| SUBHABITAT | **Dune** | **Rocky** | **Blackbrush** | **Transition** |
|---|---|---|---|---|
| N Transects | 10 | 8 | 11 | 10 |
| Total Cover* | 10712.0 | 4284.0 | 8425.0 | 9135.0 |
| Mean Cover | 1071.2 | 535.5 | 765.9 | 913.5 |
| SD | 332.1 | 249.0 | 351.6 | 412.8 |
| % Barren Ground** | 78.6 | 89.3 | 84.7 | 81.7 |
| Number of Species | 11 | 10 | 9 | 12 |

**LITTLEFIELD SITE**

| SUBHABITAT | **LA** | **LAH** | **LAC** | **WASH** |
|---|---|---|---|---|
| N Transects | 12 | 11 | 10 | 15 |
| Total Cover* | 9720.0 | 10001.0 | 10602.0 | 21521.0 |
| Mean Cover | 810.0 | 909.2 | 1060.2 | 1434.7 |
| SD | 319.2 | 296.5 | 399.7 | 579.0 |
| % Barren Ground | 83.8 | 81.8 | 78.8 | 71.3 |
| Number of Species | 4 | 5 | 5 | 11 |

* Measured in cm on 5000 cm line-intercept vegetation transects.

** Estimated by subtracting the mean cover (a) from the total number of cm of cover on a single transect (b), dividing the difference by 5000 (c), and multiplying that dividend by 100.

cover of subhabitats was: LA, 155.4 ha; LAH, 70.7 ha; LAC, 24.6 ha; and Wash, 0.23 ha.

Sixty-six plant species were identified at the Littlefield Site (Appendix IV E). The relative distribution of plant growth forms was similar to the City Creek Site (Table 1). Total aboveground biomass production of annual plants was lowest in 1990 and greatest in 1992 (Table 2, Fig. 5, App. VII). Biomass production of annual plants was significantly greater than other years in 1992, but production was not significantly different between 1990 and 1991 (Fig. 5, Table 5). Biomass production was generally poor in 1990 and 1991, but was five times greater in 1992 than in the previous two years (Table 2). Biomass production was not significantly different within any subhabitat types between 1990 and 1991; however, in 1992 biomass production was significantly different from 1990 and 1991 (App. IX). *Larrea - Ambrosia - Hilaria* subhabitat had the greatest biomass production in 1990 and 1991, but was only significantly greater than LA, and Wash subhabitats (Table 3, and App. VIII B). LAC had the least biomass production in all years (Table 3). The range of the number of species observed in subhabitats at the Littlefield Site was 7 to 22 species (Appendix X E-G). Four exotic plant species (*Bromus spp.*, *Schismus barbatus*, *Erodium cicutarium*, and *Eriogonum thomasii* ) were consistently among the top five species in biomass production. At the Littlefield Site, the greatest biomass production occurred in Wash subhabitat in 1992 (Table 3).

Perennial cover was significantly greater in Wash subhabitat than in any other subhabitat at the Littlefield Site (App XI B). Perennial cover was least in LA subhabitat. Wash subhabitat was also the most diverse, while

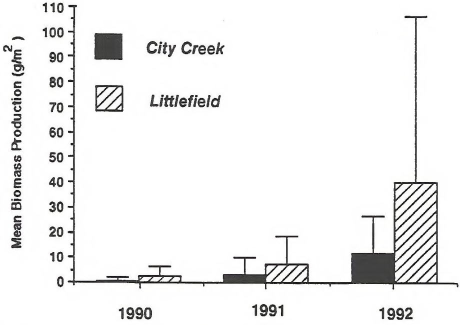


Figure 5. Among site (within years) and among years (within site) comparisons of mean aboveground dry biomass production estimates (error bars are one standard deviation from the mean) of spring annual vegetation at the City Creek and Littlefield Sites in 1990 - 1992.

Table 5. Comparisons of mean estimated aboveground dry biomass production of spring annual plants using one-way analysis of variance among sites (within years), and among years (within sites) at the City Creek and Littlefield Sites in 1990 - 1992.

***City Creek vs. Littlefield (among sites analyses)***

| **Comparison** | **F-statistic** | **p-value** |
|---|---|---|
| 1990 | 17.2 | 0.0001 |
| 1991 | 18.7 | 0.0001 |
| 1992 | 30.0 | 0.0001 |

***City Creek, Utah (among years analysis)***

| **Comparison** | **DF** | **F-statistic** | **p-value** |
|---|---|---|---|
| Overall Analysis of Variance | 398 | 46.7 | 0.0001 |
| *Among years analysis using Fisher's Protected LSD* | | | |
| 1990 vs. 1991 | | 2.7 | 0.0520 |
| 1990 vs. 1992 | | 11.6 | 0.0001 |
| 1991 vs. 1992 | | 8.9 | 0.0001 |

***Littlefield, Arizona (among years analysis)***

| **Comparison** | **DF** | **F-statistic** | **p-value** |
|---|---|---|---|
| Overall analysis of Variance | 483 | 49.0 | 0.0001 |
| *Among years analysis using Fisher's Protected LSD* | | | |
| 1990 vs. 1991 | | 5.2 | 0.2334 |
| 1990 vs. 1992 | | 37.7 | 0.0001 |
| 1991 vs. 1992 | | 32.2 | 0.0001 |

LA was the least diverse (App. XII E). Perennial plant cover ranged from 16.2% in LA subhabitat to 28.7% in Wash subhabitat (Table 4).

Comparison of the Sites. The Littlefield Site had less species of annual and perennial flora than at the City Creek Site. The Littlefield Site also had less variation in the diversity of annual plants within any given year. However, the Littlefield Site had significantly greater biomass production than the City Creek Site in all years (Fig. 5, Table 5). Annual biomass production was significantly greater in all subhabitat types at both the City Creek and Littlefield Sites in 1992 (App. IX A, B). There was little overlap of the canopies of individual perennial plants in any subhabitat except Wash subhabitat at either site. Perennial plant cover per subhabitat ranged from 10.7 - 28.7% among sites, within subhabitats (Table 4). Wash subhabitat at the Littlefield Site had the greatest total mean cover of any subhabitat at either of the two sites (App. XI A-B).

Aboveground biomass production of winter annuals can be highly variable in the Mojave Desert (Beatley 1969). During the time period from 1980 through 1991, biomass production of winter annual plants in April ranged from zero to more than 500 kg/ha (Fig. 6, App. XIII). The composite of 12 annual means for the Beaver Dam Slope, Utah in April was 141.9 ± 150.5 (SD) kg/ha (range = 0 - 525.3 kg/ha). Biomass production in the same sites for May was similar with a composite mean of 140.9 ± 159.2k (SD) (range = 0 - 546.9 kg/ha).

### *Feeding Behaviors*

Observations included several tortoise behaviors: feeding, inactivity (subsurface or surface), basking, excavating cover sites, egg-laying, courting, agonistic

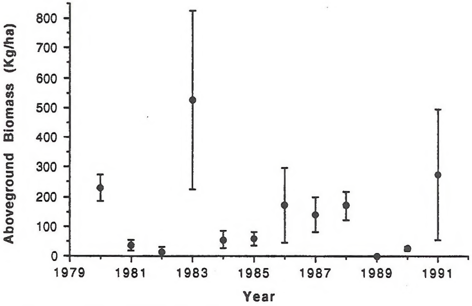


Figure 6. Aboveground dry biomass production for desert annual plants on the Beaver Dam Slope, Utah in 1980 - 1992 (Error bars indicate the standard deviation of the mean). Data from USDI - BLM (unpublished).

encounters, and travels of undetermined purposes. Feeding behaviors were counted from the first to the last bite that was taken by a tortoise during an observation. Time spent feeding also included the time spent moving from one feeding patch to another. If feeding was interrupted by another activity, such as an agonistic encounter, then the observations were logged according to the last bite prior to the switch in behavior. Feeding resumed upon the first bite subsequent to the other behavior.

Observations on desert tortoises were conducted in March through September with an emphasis in the spring months. Generally, the number of observations for months were similar among sites. However, the feeding season continued further into the summer at the City Creek Site. In four years of study, tortoises were observed for more than 2,100 hours (including times when the tortoises were not active above ground, but continued to be monitored by direct observation) (Tables 6 and 7). More than 150,000 bites of food eaten were observed to be eaten by tortoises (Tables 6 and 7).

Tortoises were observed to feed more often at the City Creek Site than at the Littlefield Site. Frequency of feeding observations occurred in greater than or equal to 50 percent of the observations at City Creek, but at the Littlefield Site tortoises were observed to feed in less than 50 percent of the observations (Table 6 and 7) .

The percentage of time spent feeding remained fairly constant at City Creek, after the first year, and was more variable at the Littlefield Site (Table 8). The mean length of foraging bouts per observation ranged from 32.6 to 43.5 minutes per observation at the City Creek Site, among years in 1989 - 1992 (Table 8). At

Table 6. Summary statistics for observations on desert tortoises at the City Creek and Littlefield Sites during the spring activity periods of 1989 - 1992.

| | Hours of Observation | Number of Observations | Hours of Feeding | % of Time Feeding | Number of Feeding Observations | Frequency of Feeding Observations | Number of Bites |
|---|---|---|---|---|---|---|---|
| ***City Creek Site*** | | | | | | | |
| April 22 - June 20,1989 | 232.5 | 92 | 35.8 | 15.4 | 43 | 47 | 11651 |
| April 8 - June 20, 1990 | 248.5 | 87 | 52.4 | 21.1 | 52 | 60 | 27852 |
| April 9 - June 19, 1991 | 230.1 | 57 | 44.0 | 19.1 | 38 | 67 | 21150 |
| April14 - June 29, 1992 | 252.1 | 81 | 55.2 | 21.8 | 49 | 61 | 37171 |
| ***Littlefield Site*** | | | | | | | |
| May 4 - June 19, 1990 | 190.9 | 58 | 12.1 | 6.3 | 24 | 41 | 7061 |
| March 29 - June 19,1991 | 252.4 | 65 | 34.7 | 13.9 | 28 | 43 | 16628 |
| April 14 - June 30, 1992 | 260.3 | 87 | 27.8 | 10.7 | 36 | 41 | 10278 |
| **SUBTOTAL*** | **1666.8** | **527** | **262** | | **270** | | **131791** |

Table 7. Summary statistics for observations on desert tortoises at the City Creek and Littlefield Sites during the summer activity periods of 1991 - 1992.

| ***City Creek Site*** | **Hours of Observation** | **Number of Observations** | **Hours of Feeding** | **% of Time Feeding** | **Number of Feeding Observations** | **Frequency of Feeding Observations** | **Number of Bites** |
|---|---|---|---|---|---|---|---|
| June 21 - October 1, 1991 | 157.1 | 47 | 9.8 | 6.2 | 34 | 72.3 | 8822 |
| July 1 - October 1, 1992 | 134.9 | 44 | 24.5 | 18.2 | 20 | 45.5 | 11953 |
| ***Littlefield Site*** | | | | | | | |
| June 20 - October 1, 1991 | 152.3 | 47 | 6.4 | 4.2 | 35 | 74.5 | 2630 |
| July 1 - October 1, 1992 | 10.8 | 3 | 0.0 | 0 | 0 | 0 | 0 |
| **TOTAL** | 455.1 | 141 | 40.7 | | 89 | | 23405 |

Table 8. Summary statistics for the length of feeding bouts by desert tortoises excluding observations when tortoises did not feed at the City Creek Site and the Littlefield Site in1989 - 1992.

| Year | Length of Observations (min.) | | | | Length of Feeding Bouts (min)* | | | Percentage of Time Feeding ** | |
|---|---|---|---|---|---|---|---|---|---|
| | *Mean* | *St dev.* | *N* | *Range* | *Mean* | *St dev.* | *Range* | *Mean* | *St. dev.* |
| ***City Creek, Utah*** | | | | | | | | | |
| 1989 | 149.4 | 75.7 | 43 | 18 - 355 | 49.9 | 50.0 | 1 - 280 | 36.0 | 28.4 |
| 1990 | 170.0 | 94.0 | 52 | 15 - 405 | 60.4 | 44.3 | 1 - 175 | 43.5 | 26.7 |
| 1991 | 234.9 | 98.0 | 38 | 35 - 445 | 69.4 | 51.2 | 1 - 279 | 32.6 | 19.1 |
| 1992 | 180.1 | 79.5 | 49 | 11 - 329 | 67.6 | 65.0 | 1 - 323 | 43.5 | 32.1 |
| ***Littlefield, Arizona*** | | | | | | | | | |
| 1990 | 184.5 | 78.8 | 24 | 33 - 310 | 30.2 | 26.0 | 1 - 80 | 19.1 | 16.7 |
| 1991 | 240.2 | 94.3 | 28 | 49 - 439 | 74.3 | 60.9 | 1 - 232 | 34.0 | 28.6 |
| 1992 | 155.6 | 77.5 | 36 | 6 - 315 | 46.3 | 39.0 | 1 - 163 | 40.8 | 35.5 |

* Mean length of actual feeding bouts

** Calculated as the average of the percentages of time spent foraging during all observations in which feeding occurred.

the Littlefield Site the mean length of observations ranged between 19.1 and 40.8 minutes per observation among years (Table 8).

### *Diet in the Northeast Mojave Desert*

Generally, the diets of tortoises were dominated by three to four food species each year. In some years, more than 75% of the bites were made up of those few species (Figs. 7 and 8). The majority of plant species in the diets of tortoises made up less than 2% of the bites in a year and the relative abundance of plant species in the diets of the tortoises varied from year to year (App. XIV A-G).

There was a relationship between the number of plant species available in the habitat and the number of species observed in the diets of tortoises (Fig. 9). However, the number of plant species observed in the tortoise diets can be affected by how much time was spent observing individual tortoises. There was a positive relationship between the number of bites observed for individual tortoises and the number of species observed in their diets (Fig. 10a, b). Therefore, small sample sizes of observations could lead to under-representation of plant species in the diets of tortoises. At the Littlefield Site the relationship between the number of bites and the number of species in the diet have similarity to the pattern at the City Creek Site data.

During years when there was a greater number of species available for tortoises to choose from, the relative proportion of exotic plants in the diet decreased (Fig. 11). There was no relationship between biomass production and the relative proportion of exotic plant species in the diet of desert tortoises (Fig. 12).

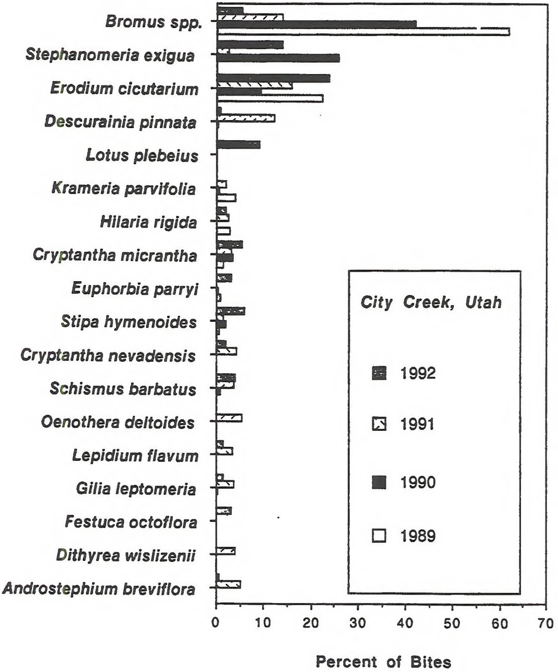


Figure 7. Plant species that were in over 2% of the bites in spring diets of desert tortoises at the City Creek in 1990 - 1992.

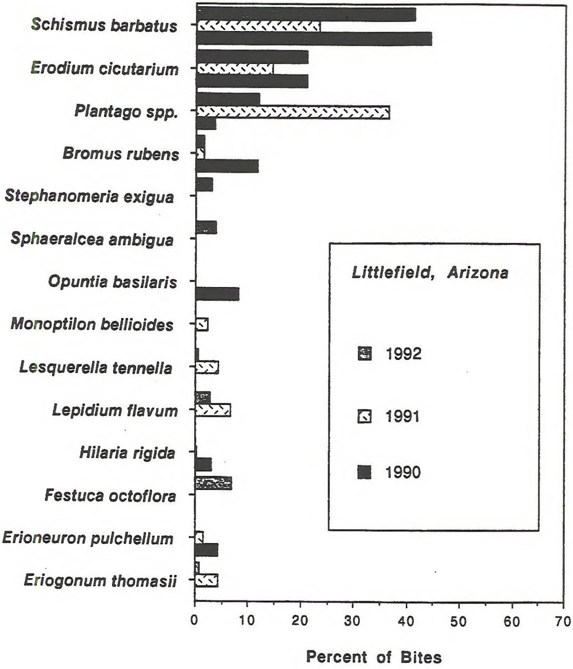


Figure 8. Plant species that were in over 2% of the bites in spring diets of desert tortoises at the Littlefield Site in 1990 - 1992.

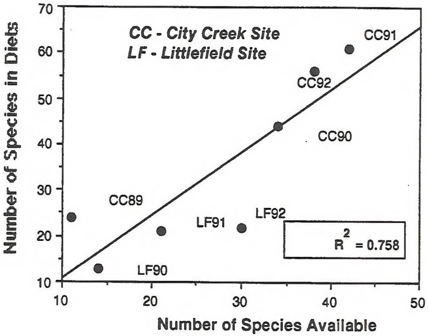


Figure 9. Relationship between the number of plant species present in desert tortoise habitats and the number of plant species in tortoise diets at the City Creek Site, and the Littlefield Site in 1989 - 1992.

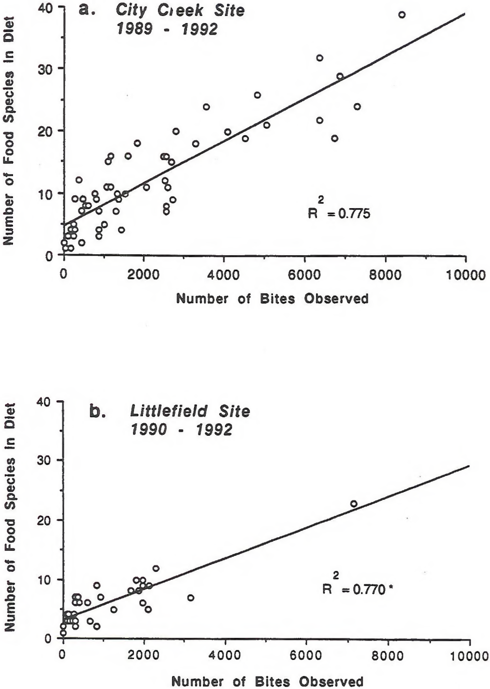


Figure 10 a-b. The relationship between the number of bites observed and the number of plant species in the diets of desert tortoises at the: (a.) City Creek Site, and (b.) Littlefield Site.

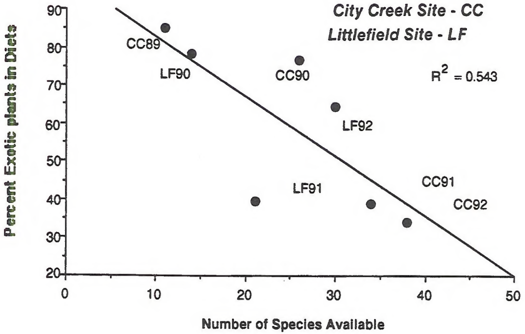


Figure 11. The relationship between the number of annual plant species available and the proportion of exotic plants in the diets of desert tortoises at the City Creek Site, and the Littlefield Site Data for 1989 - 1992.

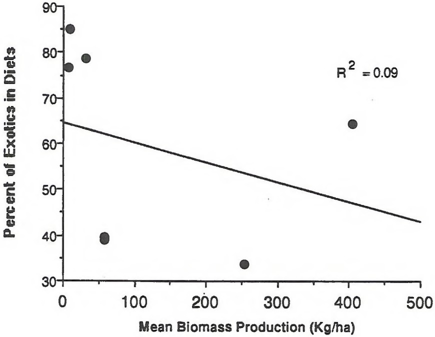


Figure 12. The relationship between biomass production and the proportion of exotic plants in the diets of desert tortoises was not significant at the City Creek Site, and Littlefield Site in 1989 - 1992.

The City Creek Site. Tortoises at the City Creek Site sampled 79 species of plants during 1989 through 1992 (Appendix XV A). Those species represented 51.9 percent of the total flora at the City Creek Site. Tortoises at the City Creek Site sampled 65 species that were not in the diet at the Littlefield Site. In 1990, these items included 26 annual forbs; 2 annual grasses; 12 perennial shrubs; 2 perennial grasses; and 2 additional items (rock and fecal material). The relative proportion of plant species among: forbs, annual grasses shrubs and perennial grasses, was similar in other years. Two of the top four species were exotics (*Bromus rubens* and *Erodium cicutarium*, Fig. 7).

The Littlefield Site. Tortoises at the Littlefield Site were observed eating 32 species of plants during 1990-1992. Those species represent 49.2 percent of the known flora of that site, including shrubs. At the Littlefield Site, tortoises ate 11 species of plants that were not in tortoises diets at the City Creek Site. There were 23 species common to the diets of tortoises at the City Creek, and Littlefield Sites. A complete list of food items consumed by the tortoises at the Littlefield Site is in App. XIII B. At the Littlefield Site, three of the top four species were introduced species (exotics) from the Mediterranean: *Schismus barbatus*, *Erodium cicutarium*, and *Bromus rubens* (Fig. 7). However, in 1991, a native annual (*Plantago patagonica)*, comprised the greatest proportion of the diet based on the number of bites at the Littlefield Site .

Woody Plants in Desert Tortoise Diets. Woody perennial plants were eaten infrequently by desert tortoises at both sites. Even though woody plants were sampled by the tortoises, *Krameria parvifolia* was the only woody perennial to be in more than 2% of the bites in any year (Fig. 7, and 8). This occurred only at the City Creek Site. In those years during which Krameria was eaten (1989,

1990 and 1991), the majority of *Krameria* plants bloomed in unison, and tortoises were observed to have purple stains on their beaks from eating the flowers. In 1992, when *Krameria* was not in more than 2% of the bites, the biomass production of annual plants at the City Creek Site was more than twice that of previous years (Fig. 5) and there was a great number of annual plants available (Fig. 9).

Cactus in Desert Tortoise Diets. Tortoises were observed eating *Opuntia erinacea*, *Opuntia basilaris*, and *Echinocereus englemannii* at the Littlefield Site; however, *O. basilaris* does not occur at the City Creek Site (App. XII A, B). Cactus was used in less than 2% of bites at the City Creek and Littlefield sites during this study.

Feces and Other Materials in Desert Tortoise Diets. Tortoises were observed eating the feces of foxes, rabbits, coyotes, cattle, and other tortoises. The relative proportion of feces in the diet of tortoises at the City Creek Site and the Littlefield Site was less than 1% of the total bites in any year (Appendix XII A-G). Tortoises were also observed eating bones (of rabbits, foxes, cattle, and other tortoises); rocks and soil (Esque and Peters, *In Press*). In addition to these other materials, arachnids were found in the feces of desert tortoises (Esque and Peters, *In Press*).

Summer Diets. As with the spring feeding period, tortoises ate plants available to them during the summer feeding period (July through September). However, during this study, the number of annual plant species found in the habitats in the summer was much lower than the number of plant species in the spring. Based on opportunistic observations, the primary summer annual food species were

*Bromus rubens and B. tectorum*, *Bouteloua aristidoides*, *Oenothera pallida*, *O. decorticans*, *Euphorbia parryi* and *E. micromera*. *Pectis papposa* can be ubiquitous in this desert after summer rains, but it was rare in the diets of tortoises. Perennial grasses also were used when available: *Stipa hymenoides*, *Muhlenburgia porteri*, *Aristida purpurea,* and *Hilaria rigida*.

### *Diet Selection in Desert Tortoises*

Previous data described the percentage of plant species that make up the diet of tortoises. Such information alone are not useful for determining diet selection. To determine diet selection, it is necessary to understand if: tortoises eat plant species with greater or lesser frequency than would be expected based on random resource use?" Toward resolution of that question, I tested the null hypothesis that: *tortoises eat species in the same frequency with which the plants occur at random the habitat*. Testing this hypothesis required using two classes of data: the frequency with which tortoises sampled different species of plants (Use) versus the frequency of occurrence of plant species in the environment (Availability). Diet selection of plants was distinguished in three classes by statistical analyses. Plants were either *avoided*, *preferred*, or *used at random* with respect to resource availability.

Diet selection was compared among years, as well as within years at each site (Table 7). Diet selection was compared among years for food plant species that had greater than 1% of the relative frequency (availability) of plants among years, and plants greater than 1% of the relative number of bites for any year. Those analyses of diet selection were limited to the number of species in the year with the fewest number of species available. Five plant species were

included in among years analyses at the City Creek Site, while four species were analyzed at the Littlefield Site (Fig. 13 - 18, App. XVI). Within year analyses of diet selection included five to eleven species at the City Creek Site (App. XVII) (Fig. 19, 20), and four to five species at the Littlefield Site (Fig. 21, 22).

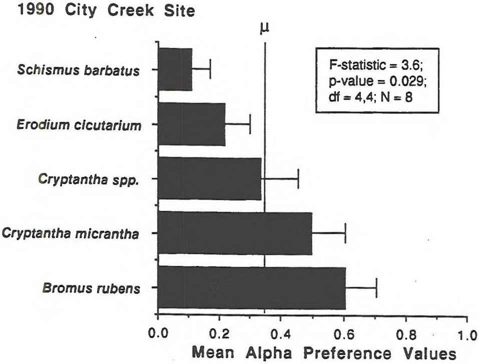


Figure 13. Means of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the City Creek Site in 1990, using food plant species that were common to all years.

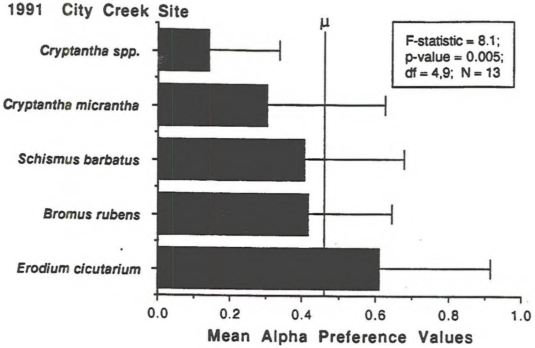


Figure 14. Means of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the City Creek Site in 1991, using food plant species that were common to all years.

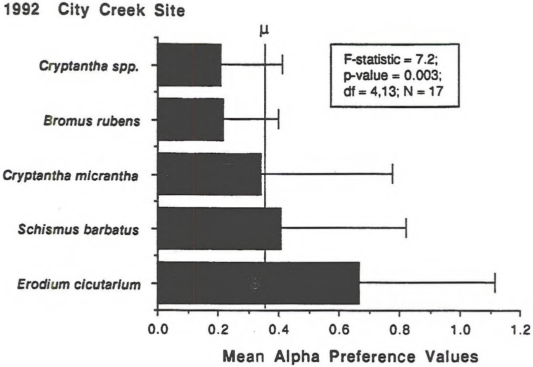


Figure 15. Mean of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the City Creek Site in 1992, using food plant species that were common to all years.

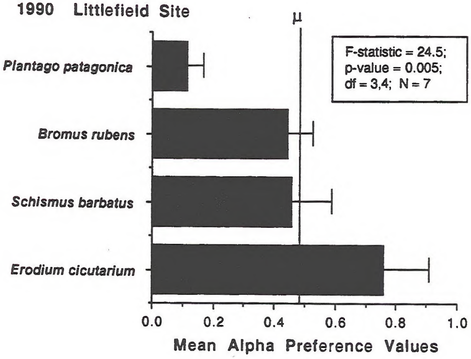


Figure 16. Means of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the Littlefield Site in 1990, using food plant species that were common to all years.

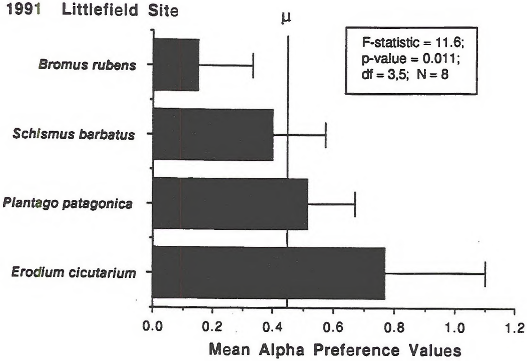


Figure 17. Means of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the Littlefield Site in 1991, using food plant species that were common to all years.

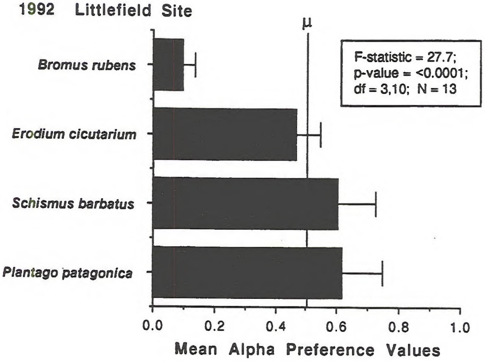


Figure 18. Means of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the Littlefield Site in 1992, using food plant species that were common to all years.

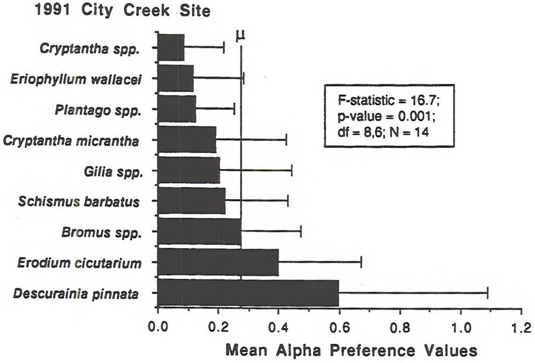


Figure 19. Mean of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the City Creek Site using food plant species that appeared in the diets in 1991.

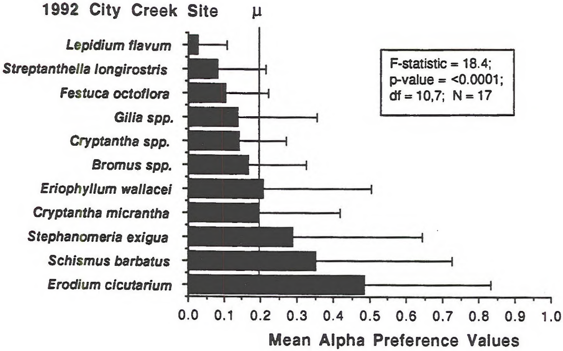


Figure 20. Mean of alpha preference values (arcsine, square-root transformed) calculated for desert tortoises at the City Creek Site using food plant species that appeared in the diets in 1992.

Table 9. Diet selection statistics using the alpha vector preference method to test the null hypothesis that tortoises selected plant species. Data for the City Creek Site and the Littlefield Site in spring 1990 - 1992.

### *Among year Comparisons*

| **Site** | **Year** | **F-statistic** | **Degrees of Freedom** | **P-value** | **Number of Animals** |
|---|---|---|---|---|---|
| CITY CREEK | 90 | 3.6 | 4, 4 | 0.0290 | 8 |
| | 91 | 8.1 | 4, 9 | 0.0050 | 13 |
| | 92 | 7.2 | 4,13 | 0.0030 | 17 |
| LITTLEFIELD | 90 | 24.5 | 3, 4 | 0.0050 | 7 |
| | 91 | 11.6 | 3, 5 | 0.0110 | 8 |
| | 92 | 27.7 | 3, 10 | < 0.0001 | 13 |

### *Within year Comparisons*

| **Site** | **Year** | **F-statistic** | **Degrees of Freedom** | **P-value** | **Number of Animals** |
|---|---|---|---|---|---|
| CITY CREEK | 90 | 3.6 | 4, 4 | 0.0290 | 8 |
| | 91 | 16.7 | 8, 6 | 0.0010 | 14 |
| | 92 | 18.4 | 10, 7 | < 0.0001 | 17 |
| LITTLEFIELD | 90 | 24.5 | 3, 4 | 0.0050 | 7 |
| | 91 | 7 | 7, 1 | 0.2830 | 8 |
| | 92 | 24.8 | 4, 9 | < 0.0001 | 13 |

Table 10a. Among and within years comparison of adjusted p-values from independent t-tests at the City Creek Site in 1990. Bonferonni's Inequality = .05/10 = 0.005. Values less than 0.005 are significantly different from random selections.

| | ***Bromus spp.*** | ***Schismus barbatus*** | ***Erodium cicutarium*** | ***Cryptantha micrantha*** | ***Cryptantha spp.*** |
|---|---|---|---|---|---|
| ***Bromus spp.*** | XXXX | | | | |
| ***S. barbatus*** | 0.0078 | XXXX | | | |
| ***E. cicutarium*** | 0.0391 | 0.3216 | XXXX | | |
| ***C. micrantha*** | 0.6036 | 0.0053 | 0.0664 | XXXX | |
| ***Cryptantha spp.*** | 0.1816 | 0.1370 | 0.4625 | 0.4001 | XXXX |

Table 10b. Among years comparison of adjusted p-values from independent t-tests at the City Creek Site in 1991. Bonferonni's Inequality = .05/10 = 0.005. Values less than 0.005 are significantly different from random selections.

| | ***Schismus barbatus*** | ***Bromus spp.*** | ***Erodium cicutarium*** | ***Cryptantha micrantha*** | ***Cryptantha spp.*** |
|---|---|---|---|---|---|
| ***S. barbatus*** | XXXX | | | | |
| ***Bromus spp.*** | 0.6423 | XXXX | | | |
| ***E. cicutarium*** | 0.2565 | 0.2294 | XXXX | | |
| ***C. micrantha*** | 0.3993 | 0.1660 | 0.0072 | XXXX | |
| ***Cryptantha spp.*** | 0.0457 | 0.0040 | 0.0002 | 0.0214 | XXXX |

Table 10c. Among years comparison of adjusted p-values from independent t- tests at the City Creek Site in 1992. Bonferonni's Inequality = .05/10 = 0.005. Values less than 0.005 are significantly different from random selections.

| | *Bromus spp.* | *Erodium cicutarium* | *Cryptantha micrantha* | *Schismus barbatus* | *Cryptantha spp.* |
|---|---|---|---|---|---|
| *Bromus spp.* | XXXX | | | | |
| *E. cicutarium* | 0.0036 | XXXX | | | |
| *C. micrantha* | 0.2744 | 0.1128 | XXXX | | |
| *S. barbatus* | 0.0785 | 0.1432 | 0.7113 | XXXX | |
| *Cryptantha spp.* | 0.9147 | 0.0059 | 0.1196 | 0.1328 | XXXX |

Table 10d. Within and among years comparison of adjusted p-values from independent t-tests at the Littlefield Site in 1990. Bonferonni's Inequality = .05/6 = 0.0083. Values less than 0.0083 are significantly different from random selections.

| | ***Bromus* spp.** | ***Schismus barbatus*** | ***Erodium cicutarium*** | ***Plantago* spp.** |
|---|---|---|---|---|
| ***Bromus* spp.** | XXXX | | | |
| ***S. barbatus*** | 0.9142 | XXXX | | |
| ***E. cicutarium*** | 0.1981 | 0.3065 | XXXX | |
| ***Plantago* spp.** | 0.0395 | 0.0668 | 0.0028 | XXXX |

Table 10e. Among years comparison of adjusted p-values from independent t-tests at the Littlefield Site in 1992. Bonferonni's Inequality = .05/6 = 0.0083. Values of less than 0.0083 are significantly different from random selections.

| | ***Bromus spp.*** | ***Schismus barbatus*** | ***Erodium cicutarium*** | ***Plantago spp.*** |
|---|---|---|---|---|
| ***Bromus spp.*** | XXXX | | | |
| ***S. barbatus*** | 0.0019 | XXXX | | |
| ***E. cicutarium*** | 0.0019 | 0.3397 | XXXX | |
| ***Plantago spp.*** | 0.0026 | 0.9606 | 0.4463 | XXXX |

Table 11a. Within years comparison of adjusted p-values from independent t-tests at City Creek, Utah in 1991.
Bonferonni's Inequality = .05/36 = 0.0014. Values of less than 0.0014 are significantly different from random selections.

| | Schismus barbatus | Bromus spp. | Plantago spp. | Eriophyllum wallacei | Erodium cicutarium | Cryptantha micrantha | Descurainia pinnata | Gilia spp. | Cryptantha spp. |
|---|---|---|---|---|---|---|---|---|---|
| S. barbatus | XXXX | | | | | | | | |
| Bromus spp. | 0.3916 | XXXX | | | | | | | |
| Plantago spp. | 0.2030 | 0.0348 | XXXX | | | | | | |
| E. wallacei | 0.2016 | 0.0543 | 0.8422 | XXXX | | | | | |
| E. cicutarium | 0.0892 | 0.0816 | 0.0017 | 0.0004 | XXXX | | | | |
| C. micrantha | 0.7395 | 0.3909 | 0.3169 | 0.2360 | 0.0453 | XXXX | | | |
| D. pinnata | 0.0290 | 0.0769 | 0.0096 | 0.0081 | 0.3237 | 0.0236 | XXXX | | |
| Gilia spp. | 0.8421 | 0.3557 | 0.1522 | 0.3139 | 0.0459 | 0.9017 | 0.0450 | XXXX | |
| Cryptantha spp. | 0.0647 | 0.0161 | 0.3602 | 0.6024 | 0.0024 | 0.0254 | 0.0036 | 0.1106 | XXXX |

Table 11b. Within year comparison of adjusted p-values from independent t-tests at City Creek, Utah in 1992. Bonferonni's Inequality = .05/55 = 0.0009. Values of less than 0.0009 are significantly different from random selections.

| | ***Bromus* spp.** | ***Festuca octaflora*** | ***Erodium cicutarium*** | ***Cryptantha micrantha*** | ***Eriophyllum wallacei*** | ***Streptanthella longirostris*** | ***Gilia* spp.** | ***Schismus barbatus*** | ***Stephanomeria exigua*** | ***Lepidium flavum*** | ***Cryptantha* spp.** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Bromus* spp.** | XXXX | | | | | | | | | | |
| ***F. octaflora*** | 0.0001 | XXXX | | | | | | | | | |
| ***E. cicutarium*** | 0.0051 | 0.0006 | XXXX | | | | | | | | |
| ***C. micrantha*** | 0.7279 | 0.1877 | 0.0346 | XXXX | | | | | | | |
| ***E. wallacei*** | 0.6710 | 0.1617 | 0.0303 | 0.8844 | XXXX | | | | | | |
| ***S. longisrostris*** | 0.0708 | 0.6315 | 0.0012 | 0.0686 | 0.1531 | XXXX | | | | | |
| ***Gilia* spp.** | 0.5760 | 0.6468 | 0.0134 | 0.2819 | 0.4875 | 0.4444 | XXXX | | | | |
| ***S. barbatus*** | 0.0520 | 0.0232 | 0.3020 | 0.2280 | 0.2569 | 0.0100 | 0.0926 | XXXX | | | |
| ***S. exigua*** | 0.2679 | 0.0751 | 0.2053 | 0.2300 | 0.4995 | 0.0346 | 0.1356 | 0.6870 | XXXX | | |
| ***L. flavum*** | 0.0010 | 0.0160 | 0.0001 | 0.0074 | 0.0329 | 0.1842 | 0.0543 | 0.0026 | 0.0140 | XXXX | |
| ***Cryptantha* spp.** | 0.5099 | 0.3852 | 0.0043 | 0.3186 | 0.4412 | 0.1290 | 0.9249 | 0.0489 | 0.0949 | 0.0087 | XXXX |

Table 11c. Within year comparison of adjusted p-values from independent t-tests at the Littlefield Site in 1992. Bonferonni's Inequality = .05/10 = 0.005. Values less than 0.005 are significantly different from random selections.

| | ***Bromus spp.*** | ***Schismus barbatus*** | ***Erodium cicutarium*** | ***Lepidium flavum*** | ***Plantago spp.*** |
|---|---|---|---|---|---|
| ***Bromus spp.*** | XXXX | | | | |
| ***S. barbatus*** | 0.0021 | XXXX | | | |
| ***E. cicutarium*** | 0.0023 | 0.3928 | XXXX | | |
| ***L. flavum*** | 0.6889 | 0.0019 | 0.0064 | XXXX | |
| ***Plantago spp.*** | 0.0031 | 0.8867 | 0.4335 | 0.0128 | XXXX |

Diet Selection Among Years. At the City Creek Site, five plant species were abundant enough in all years to be analyzed for their importance in diet selection by desert tortoises among years: *Erodium cicutarium*, *Cryptantha spp.* (*C. virginensis* and *C. nevadensis*), *Schismus barbatus*, *Cryptantha micrantha*, and *Bromus spp.* (*B. rubens* and *B. tectorum*) (Fig. 13 - 15). The null hypothesis that all diet plants were eaten by tortoises equally with respect to their availability was rejected in all years at the City Creek Site (Table 9). For years in which the null hypothesis was rejected it was possible to complete *post hoc* analyses of significance for diet selection using multiple paired t-tests with adjusted p-values (Tables 10a-e). In these analyses, all combinations of species included in the analysis were tested to determine if the mean alpha preference values for the species were significantly different. The critical values for the t-tests were adjusted to control for experiment-wise error using Bonferonni's Inequality (see Methods). *Erodium cicutarium* was preferred over *Cryptantha spp.* in 1991 and 1992, and also preferred over *Bromus spp.* in 1992 (Fig. 13 - 15, and Tables 10a-c). *Bromus spp.* were significantly preferred over *S. barbatus* in 1990 and also preferred over *Cryptantha spp.* in 1992 (Fig. 13 - 15, and Table 10a and c). *Cryptantha micrantha* was the only native plant to be selected over other species in any year (Fig. 13; Table 10a).

At the Littlefield Site, four plant species were abundant enough in the habitat and feeding observations for inclusion in among years analyses: *Bromus spp.* (*B. rubens and B. tectorum*), *Schismus barbatus*, *Erodium cicutarium*, and *Plantago spp.* (*P. patagonica* and *P. insularis*) (Fig. 16 - 18). The null hypothesis (species were eaten in the same proportion to their occurrence in the habitats) was rejected in 1990 and 1992, but not in 1991 (Table 9). *Bromus spp.* were avoided or eaten at random with respect to availability in all three years.

*Bromus spp.* were also significantly avoided among all other species in 1992 (Table 10e). *Erodium cicutarium* was either preferred or eaten at random with respect to availability in all years. *Plantago spp.* were the only native species that were the most preferred plant species in any year. There were no species, among those analyzed, that were always preferred or always avoided at the City Creek Site, or the Littlefield Site.

Diet Selection Within Years. Among years analyses of diet selection were restrictive, but necessary to determine whether there was a pattern of variability in the selection of plant species over the years of the research. Focusing on diet selection within a single year allows a less restrictive analysis (i.e. considering a greater number of plant species within a year, because each year is not dependent upon other years that had a lesser number of species available).

At the City Creek Site, the null hypothesis (no diet selection for the within-year analysis) was rejected all years (Table 9, Fig. 13 and, 23 - 24). There were 13 plant species available for within year analyses of diet selection. The number of plant species used for within year analyses of diet selection differed in 1990 (five species), 1991(nine species), and 1992 (11 species). For 1990 the within year analysis of diet selection at the City Creek Site were the same plant species as the among year analysis (Fig. 13, Table 11a). No plant species had the same preference rank for three consecutive years at the City Creek Site (Fig. 13, and 23 - 24). *Erodium cicutarium* was preferred over *Plantago spp.*, *Eriophyllum wallacei*, and *Cryptantha spp.* in 1991 (Table 10a) and was also preferred over *Strepanthella longirostris* and *Lepidium flavum* in 1992 (Table 11b). *Bromus spp.* was preferred over *Lepidium flavum* in 1992 (Table 11b). No

native plants were the most preferred plants in the within year analysis of diet selection at the City Creek Site (Table 11a - b).

At the Littlefield Site, eight species were used for the within-year analysis in 1990 - 1992 (Fig. 13, 21 - 22). The null hypothesis (no diet selection) was rejected in 1990 and 1992, but not in 1991(Table 9). The same plant species were used in among year analyses and within year of diet selection in 1990; thus, the same table and figure was used (Table 10d, Fig. 16). Plant species in 1992 had the most significant contrasts of selection in any one year. *Bromus spp.* were avoided compared to *S. barbatus*, *E. cicutarium*. *Plantago spp.* and *L. flavum* was avoided when it was compared to *S. barbatus* and *E. cicutarium* in 1992 (Table 11c).

Plant Species Not Included in Statistical Analyses. Numerous plant species were eliminated, because they were too rare in the habitat to be included the statistical analyses. Conversely, there were also several plant species that were rarely eaten but were abundant in the habitat.

There were more plant species that were abundant but not eaten, than species that were rare but eaten in abundance. Of note were the common plants: *Eriastrum eremicum*, *Eriogonum thomasii*, *Monoptilon bellioides*, and *Festuca octoflora*. *Eriastrum eremicum* was ubiquitous at both sites but, tortoises did not eat it. Even when tortoises approached and sniffed *Eriastrum*, they were not observed eating any. *Eriogonum thomasii* was abundant in the desert in 1992, and its biomass was substantial. However, tortoises paid little attention to it in any phenological stage. *Festuca octoflora* was only abundant in 1992, but was also avoided by tortoises.

There were several species that tortoises were apparently good at finding (based on relative percentage of bites - App. XII), in some years, but were encountered only rarely during vegetation transects. These species included *Androstephium breviflorum*, *Euphorbia parryi*, *Gilia leptomeria*, and *Lotus plebieus* .

Another small class of plants were eaten so rarely that they did not appear in either the standard feeding observations or vegetation transects. These plants included: *Oenothera pallida*, *Alliona incarnata*, and *Abronia fragrans*. *Oenothera pallida* grew at the City Creek Site in small patches of less than 5 m diameter during the study. In years of low biomass production, a patch of *O. pallida* may consist of one plant; however, in years of high production, several plants comprised one patch of several square meters. Apparently, tortoises fed on the plants heavily when they found them, because the plants frequently had tortoise tracks and fecal material around them, and the plants were almost barren of leaves as high as tortoises could reach. This phenomenon occurred at all of five patches of *O. pallida* that we observed.

Perennial Grasses. Perennial grasses were eaten in greater frequency than they occurred on vegetation transects. In some cases this may be due to sampling error, because perennial grasses were relatively rare and thus not recorded with the same regularity as annual plants.

Woody Perennial Plants. Woody plants were abundant, but they were rarely eaten. Those species were eliminated from the diet selection analyses,

because feeding obvservations indicated that, except for *Krameria parvifolia*, woody perennials were not important items in tortoise diets during spring feeding at the City Creek Site, and the Littlefield Site. Selection data for woody plants corroborates the data reported for the relative percentages of woody plants in the diets of tortoises. In 1991, perennial plant frequencies were collected in conjunction with annual plant frequencies on the same transects at the City Creek Site (Appendix IXA). Ten species of woody plants occurred on vegetation quadrats at the City Creek Site in 1991, but only three species were eaten rarely during observations. *Coleogyne ramosissima* and *Gutierrezia sp.* were eaten on one patch each. *Krameria parvifolia* was eaten on more patches than it occurred on random vegetation quadrats (17 feeding patches: 7 vegetation quadrats). The role of *K. parvifolia* is discussed later.

Relative Proportions of Grasses and Forbs in Diets. Selection of forbs in relation to grasses was analyzed to determine the relative proportions of grasses to forbs in the diet of tortoises and whether or not the proportions changed relative to plant availability.

At the City Creek Site, tortoises fed on a greater proportion of grasses than herbaceous annual plants in years of low biomass production and when the lowest numbers of annual plant species were available (Fig. 23a). Conversely, during 1991 and 1992 when biomass production was relatively greater than the previous years, tortoises fed on a greater proportion of herbaceous annual plants. In contrast, tortoises at the Littlefield Site fed on a greater proportion of annual herbaceous plants in years of low biomass production and when low numbers of plant species were available (Fig. 23b). This effect diminished with greater biomass production and greater numbers of plant species until the

relative proportions were almost equal in 1992 (Fig. 23b). When considered only on the basis of diet proportions, these results appear to be confounding. However, there was a positive correlation between the percentage of biomass production of grasses when compared to the percentage of grasses in the diets of tortoises (Fig. 24).

Generally, tortoises fed upon a greater proportion of herbaceous plants than grasses in the early spring (April - May), and shifted their emphasis to grasses later into the spring and summer (June-July) (Figs. 25 - 30). As the available biomass increased, there was a greater proportion of annual grasses in the diet (Fig. 24).

General Trends in Diet Selection. Trends in diet selection were similar to trends in the relative percentage of bites eaten relative to species availability. Tortoises selected more species of plants when more plant species were available. This trend existed at individual sites, among years, and among sites for given years. For example, tortoises always selected more plant species at the City Creek Site, which had the greatest number of plant species available in any year. The years of greatest contrast were 1990 versus 1992. The greater diversity of plants available in 1992 may have provided tortoises with an opportunity for selection not present in other years.

Diet Selection Related to the Dispersion and Available Biomass of Annual Plant Species. Diet selection was investigated in relation to the biomass production of plant species in the habitat, and the dispersion of species available across the habitats to determine if $\alpha$-preference values were

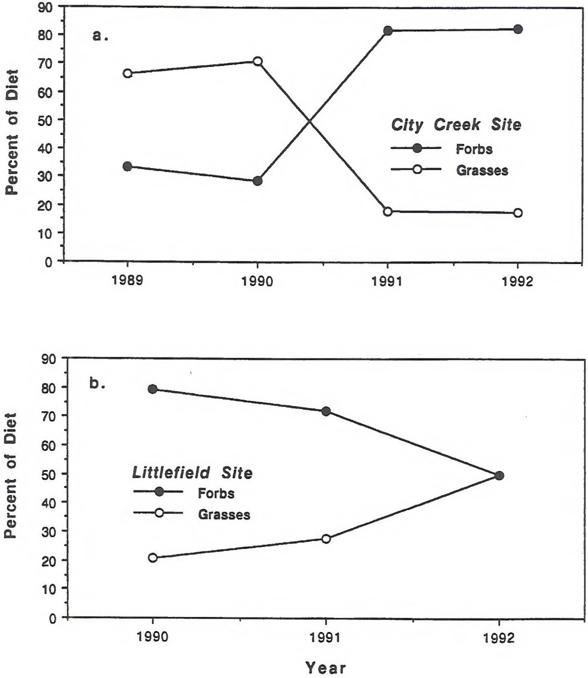


Figure 23a-b. Percents of grasses and forbs in the spring diets of desert tortoises at the (a.)City Creek Site in 1989 - 1992 and the (b.)Littlefield Site in 1990 - 1992.

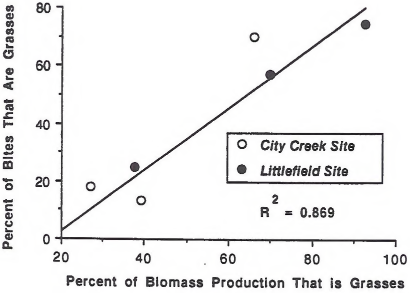


Figure 24. Percentage of annual grass biomass production compared to the amount of annual grasses in the diet of desert tortoises at the City Creek Site and the Littlefield Site in 1990 - 1992.

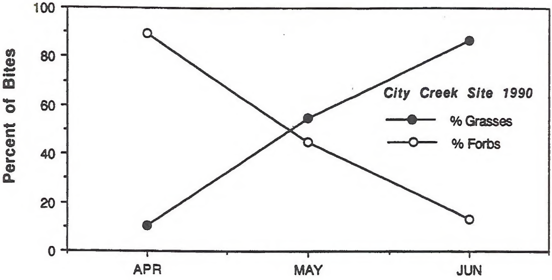


Figure 25. Percentages of grasses and forbs in the spring diets of desert tortoises at the City Creek Site in 1990.

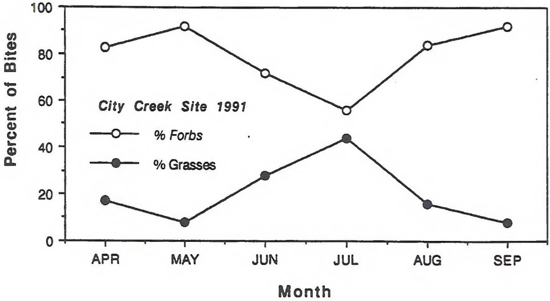


Figure 26. Percentages of grasses and forbs in the spring diets of desert tortoises at the City Creek Site in 1991.

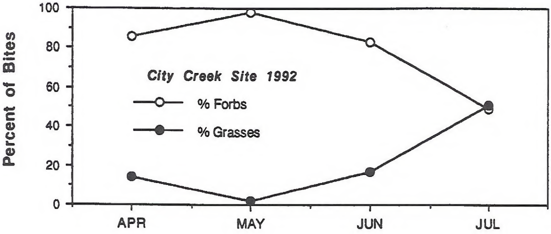


Figure 27. Percentages of grasses and forbs in the spring diets of desert tortoises at the City Creek Site in 1992.

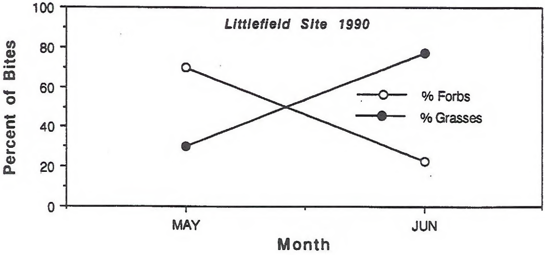


Figure 28. Percentages of grasses and forbs in the spring diets of desert tortoises at the Littlefield Site in 1990.

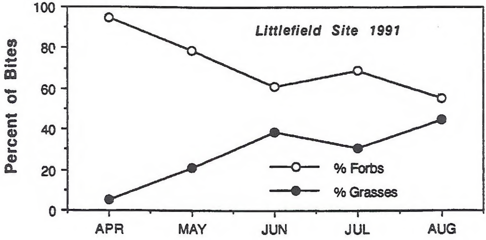


Figure 29. Percentages of grasses and forbs in the spring diets of desert tortoises at the Littlefield Site in 1991.

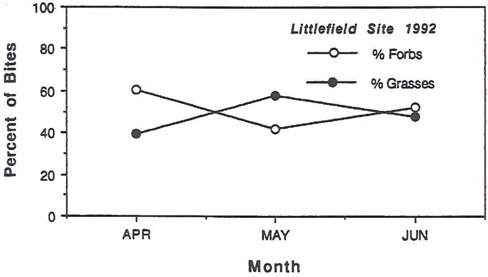


Figure 30. Percentages of grasses and forbs in the spring diets of desert tortoises at the Littlefield Site in 1992.

dependent upon biomass production or dispersion of plant species in selection analyses.

Prior to investigating the relationship between dispersion or biomass production of plant species to selection, analyses were completed to determine the extent to which dispersion was dependent upon biomass production. Explained variance for the relationship between biomass production and dispersion was higher at the City Creek Site, and the Littlefield Site in 1990 than in 1991 (Fig. 31 - 33). Data for City Creek and Littlefield indicate that single outliers were responsible for low $r^2$ values in 1991 (Fig. 32 and 34). Production estimates for those years (Fig. 5) indicate that dispersion was correlated more closely with biomass production in years of low biomass production.

Some plant species have a predisposition for great biomass production. Therefore, plant species may have equal frequencies, but differ in biomass. This difference in biomass could lead to differences in diet preference due to benefits of selecting plants that provide the greatest bulk of food for time invested. However, there was no relationship between biomass production and selection (Fig. 35 - 40, App. XI, XIV A, B).

The level of aggregation or dispersion could affect plant availability or the ability of tortoises to find plants. This, in turn, could affect selection of plant species. There was no relationship between the dispersion of plants species that tortoises ate and their preference for those plants (Fig. 41 - 44).

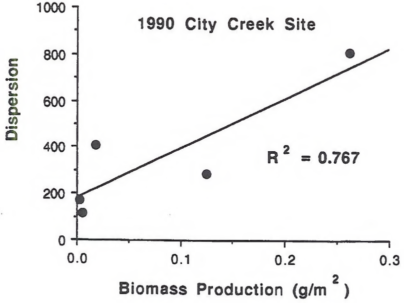


Figure 31. Biomass production compared to dispersion [(Variance/Mean)*(N-1)] of annual plant species at the City Creek Site in 1990.

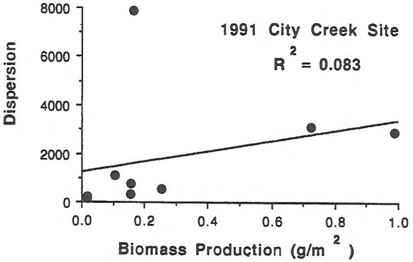


Figure 32. Biomass production compared to dispersion [(Variance/Mean)*(N-1)] of annual plant species at the City Creek Site in 1991.

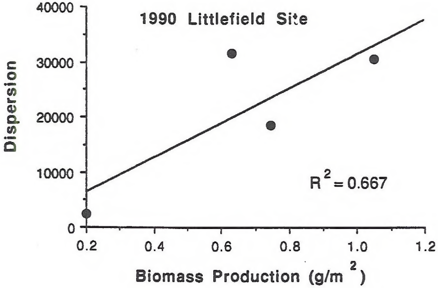


Figure 33. Biomass production compared to dispersion [(Variance/Mean)*(N-1)] of annual plant species at the Littlefield Site in 1990.

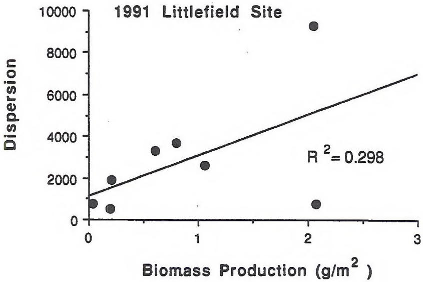


Figure 34. Biomass production compared to dispersion [(Variance/Mean)*(N-1)] of annual plant species at the Littlefield in 1991.

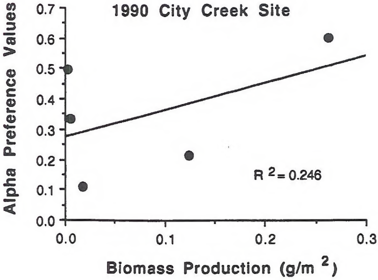


Figure 35. Biomass production compared to mean alpha preference for spring annual plants at the City Creek Site in 1990.

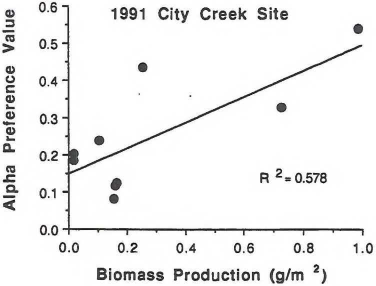


Figure 36. Biomass production compared to mean alpha preference for spring annual plants at the City Creek Site in 1991.

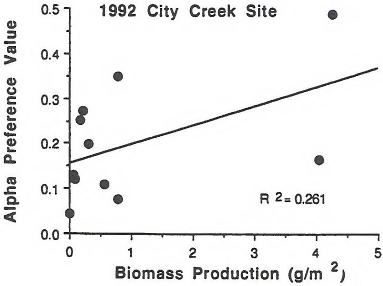


Figure 37. Biomass production compared to mean alpha preference values for spring annual plants at the City Creek Site in 1992.

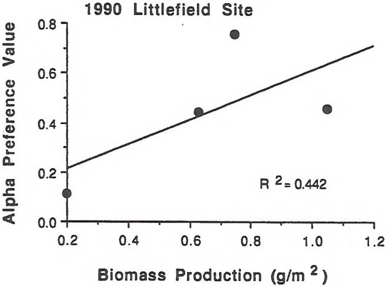


Figure 38. Biomass production compared to mean alpha preference values for spring annual plants at the Littlefield Site in 1990.

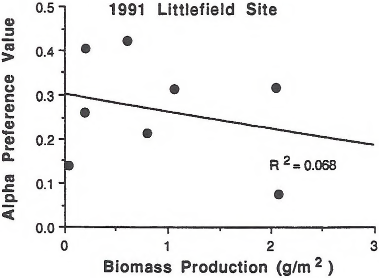


Figure 39 . Biomass production compared to mean alpha preference values for annual plants at the Littlefield Site in 1991.

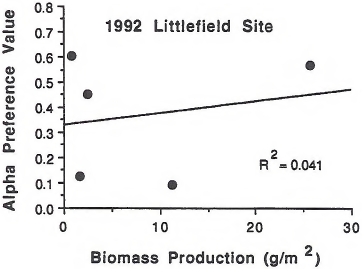


Figure 40. Biomass production compared to mean alpha preference values for annual plants at the Littlefield Site in 1992.

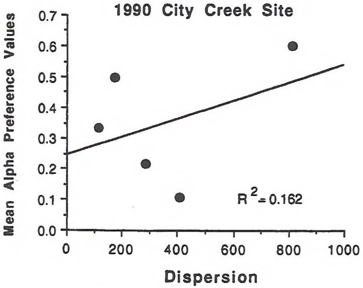


Figure 41. Dispersion [(Variance/Mean)*(N-1)] of spring annual plants compared to mean alpha preference calculations for those species at the City Creek Site in 1990.

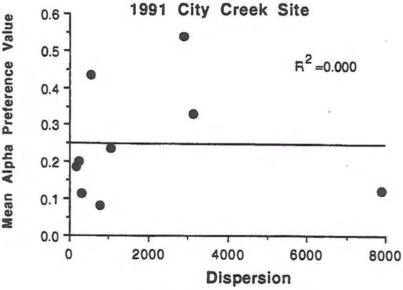


Figure 42. Dispersion [(Variance/Mean)*(N-1)] of spring annual plants compared to mean alpha preference calculations for those species at the City Creek Site in 1991.

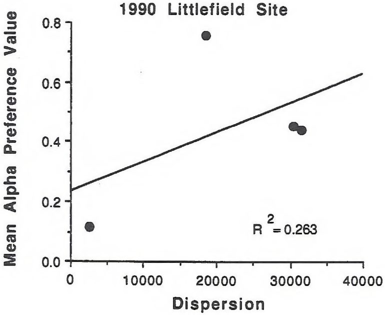


Figure 43. Dispersion [(Variance/Mean)*(N-1)] of spring annual plants compared to mean alpha preference calculations for those species at the Littlefield Site in 1990.

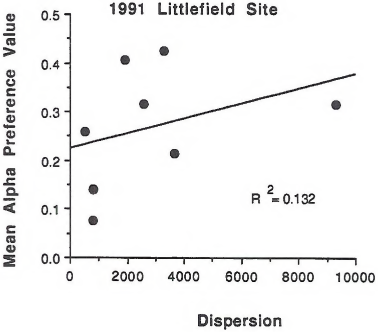


Figure 44. Dispersion [(Variance/Mean)*(N-1)] of spring annual plants compared to mean alpha preference calculations for those species at the Littlefield Site in 1991.

### *Diet Selection Along Feeding Routes*

Diet selection analyses along the feeding routes of desert tortoises employed a subset of the previous analysis. The question is asked, do tortoises feed at random with respect to what is available to them within one-square meter feeding patches? This analysis occurs at a much finer spatial scale than the previous analyses. Diet selection along feeding routes was measured at both sites in 1992. Comparisons of feeding route selection were conducted on observations that had $\geq$ 6 feeding patches.

The City Creek Site. Fifteen desert tortoises were observed (45 observations) from 4 May - 4 July 1992. Each tortoise was observed one to six times. The number of feeding patches per observation ranged from 6 - 64 (avg. = 19.1$\pm$ 12.2 SD; Appendix XV A, B). I recorded 54 annual and 27 perennial plant species on transects and tortoises were observed eating 33 and 18 plant species, respectively. The frequency of plant species occurring on vegetation transects at random throughout the study plot did not differ significantly from the frequency of plant species found on feeding patches (Fig. 37).

Diet selection was analyzed using regression (frequency of plant species available along feeding routes, to the frequency of plant species that were eaten by tortoises during observations). Tortoises preferred *Cryptantha micrantha*, *Erodium cicutarium*, *Stephanomeria exigua*, *Lotus plebieus*, and *Euphorbia parryi*. Tortoises avoided *Festuca octoflora*, *Descurainia pinnata*, and *Streptanthella longirostris*, *Eriophyllum wallacei*, and *Eriastrum eremicum* at the City Creek Site (Fig. 38). *Bromus spp.*, *Cryptantha spp.*, *Gilia spp.*,

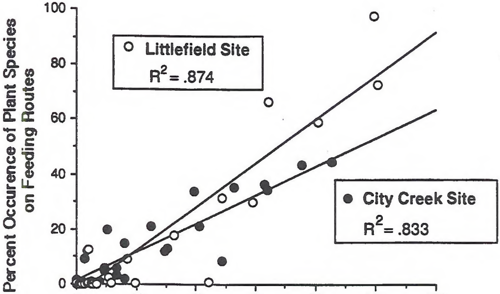
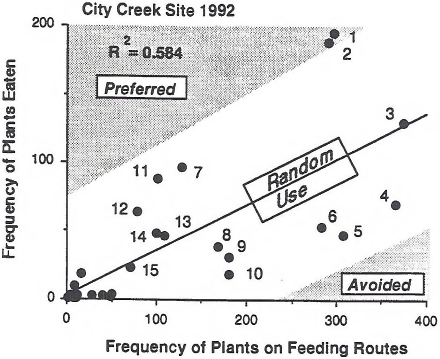


Figure 45. Comparison of plant species availability on random transects throughout the habitat to plant species availability on desert tortoise feeding routes at the City Creek Site and the Littlefield Site in 1992.



Labels for plant species in Figure 46

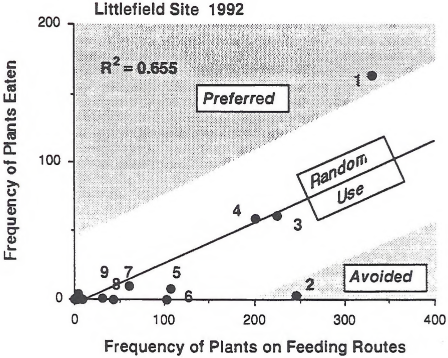
| | | | |
|---|---|---|---|
| 1 | *Cryptantha micrantha* | 9 | *Eriophyllum wallacei* |
| 2 | *Erodium cicutarium* | 10 | *Eriastrum eremicum* |
| 3 | *Bromus spp.* | 11 | *Lotus plebius* |
| 4 | *Festuca octoflora* | 12 | *Euphorbia parryi* |
| 5 | *Descurainia pinnata* | 13 | *Gilia spp.* |
| 6 | *Streptanthella longirostris* | 14 | *Schismus barbatus* |
| 7 | *Stephanomeria exigua* | 15 | *Plantago spp.* |
| 8 | *Cryptantha spp.* | | |

Figure 46. Diet selection of desert tortoises along daily feeding routes. Values below the regression line are avoided, values above the regression line are preferred and values on the regression line are eaten at random with respect to availability. at the City Creek Site in 1992 (Error bars are the 95% confidence interval around the mean).

*Schismus barbatus*, and *Plantago spp.* appeared to be eaten at random relative to availability.

The Littlefield Site. I observed 11 tortoises (21 observations) along foraging routes from 11 May - 19 June 1992. There were 6 - 53 feeding patches recorded (avg. = 16.2±11.0 SD ; App. XV B). There were 20 annual plant species on vegetation transects and eight perennial plant species. Tortoises fed upon eight annual species and three perennial species. The frequency of plant species on random vegetation transects was not significantly different to the frequency of plant species found along the routes traveled by tortoises at the Littlefield Site (Fig. 47). *Schismus barbatus* was the only plant species that appeared to be preferred in this analysis (Fig. 47). *Bromus spp.*, *Monoptilon bellioides*, and *Eriogonum thomasii* were avoided. *Erodium cicutarium* and *Plantago spp.* appeared to be eaten at random with respect to availability.

Comparison of Diet Selection Along Feeding Routes Relative to the Entire Habitat. The analysis of diet selection along feeding routes is a different spatial scale from the analysis of diet for the entire study plot. The percent frequency of species present along foraging routes was similar to the percent frequency of plant species on random vegetation transects throughout the study plot at the City Creek Site and the Littlefield Site ($R^2 = 0.833$ and 0.874, respectively). Tortoises do not appear to select routes on which to forage that are significantly different from random.



Labels for plant species in Figure 47

| | |
|---|---|
| 1 *Schismus barbatus* | 6 *Monoptilon bellioides* |
| 2 *Bromus spp.* | 7 *Lepidium flavum* |
| 3 *Erodium cicutarium* | 8 *Lesquerella tenella* |
| 4 *Plantago spp.* | 9 *Chorizanthe rigida* |
| 5 *Eriogonum thomassii* | |

Figure 47. Diet selection of desert tortoises along daily feeding routes. Values below the regression line are avoided, values above the regression line are preferred, and values on the regression line are eaten at random with respect to availability at the Littlefield Site in 1992 (Error bars are the 95% confidence interval around the mean).

# DISCUSSION

## *Characteristics of the Study Sites*

The City Creek Site and the Littlefield Site are significantly different in topography, soils, incidence of rainfall, and other features. These characteristics translate into variation in perennial plant cover, availability of drinking water and food resources. Consequently, the plants species available for diets differ. The Littlefield Site consistently had greater biomass production of plants than the City Creek Site. However, the City Creek Site has a consistently greater diversity of annual plant species available for tortoises to feed upon than the Littlefield Site. How tortoises respond to this variation is yet to be explained. My purpose is to explore the patterns of diet and diet selection and how variability of resource availability affects tortoises as individuals and as populations.

Biomass Production Data Relative to Other Sites in the Mojave Desert. Aboveground biomass production estimates reported here are within the variance of biomass estimates measured across the Beaver Dam Slope (BDS), Utah, in comparable years (USDI-BLM, unpublished data, App. XI). Furthermore, my production estimates also are within the range of estimates for Mojave Desert ecosystems in southern Nevada (Beatley 1969) and California (Turner et al. 1984). For example, Turner et al. (1984) published biomass estimates of 85 kg/ha in a productive year (1980) and 0.7 kg/ha in a drought

year (1981). The variability of food resources measured among these sites from 1989 - 1992 represents the full spectrum of resource availability at these sites.

### *Diet and Diet Selection of Desert Tortoises*

Characteristics of Diets. Desert tortoises eat a variety of materials including: fresh winter and summer annual vegetation, cured annual plants, litter from plants, and perennial plants (Luckenbach 1982, Esque et al 1991, this Thesis, Jennings 1993, and Van Devender 1993); arthropods (Hansen et al. 1976; Esque et al. 1991; Avery, H - *pers. comm.*); bones and soil (Marlow and Tollestrup 1982, Esque and Peters *In Press*); feces of vertebrates including those of other tortoises (Hansen et al. 1976, and Luckenbach 1982); and rare items such as bird feathers and lizard skins (Hansen et al. 1976).

Desert tortoise diets are diverse. Over 60 species of plants occur in the diets of tortoises, at different sites in the Mojave and Sonoran Deserts (this Thesis, Jennings 1993, and Van Devender et al. 1993). Possibly, if tortoises are observed long enough, they may sample all of the materials that are available in their habitats. However, tortoise diets at the City Creek Site and the Littlefield Site consist primarily of annual plant species.

The composition of desert tortoise diets can also be highly variable among years. This variability appears to be caused partially by differences in the available flora at different sites. The relative proportions of plant species in the diets at the City Creek Site and the Littlefield Site can be affected by the number of species available.

Nagy and Medica (1986) found that the tortoises restricted their diets to only four of 25 (16%) plant species available in Rock Valley, Nevada. In contrast, tortoises at the City Creek Site and the Littlefield Site each fed upon ~50% of the species present at each study site. The diversity of diets was much greater in my studies with 32 species eaten at the Littlefield Site, and 79 species eaten at the City Creek Site over the course of four years. However, site differences and intensity of sampling likely contributed largely to the differences in diets between Rock Valley, Nevada and those in my study. Variation in availability of food resources due to plant community and annual variation, and intensity of sampling can have profound effects on the results of diet surveys.

Effects of Study Design on Results and Conclusions. Small sample sizes of animals, and few or infrequent observations on individual animals can cause under representation of species diversity in diets. The large variability in data among sites, years, and individuals requires thorough surveys of diets over several years to ensure that diets have been sampled adequately across a range of possibilities for diet availability.

Woody Shrubs, Trees, and Cactus in the Diets of Desert Tortoises. Few perennial shrubs, trees and cactus were in the diet of tortoises at the City Creek Site and the Littlefield Site. Woody plants have more indigestible plant components, such as lignin and secondary compounds, than do annual plants. Thus, woody plant species are less palatable to tortoises than are annuals. Perennial woody shrubs also tend to be tall in growth form, that is less accessible to ground-dwelling herbivores like tortoises.

Tortoises appear to eat cactus in some parts of the Mojave Desert during years when few annuals are available and perennial plants do not produce leaves. The majority of tortoise fecal pellets that were checked opportunistically at a 1.6 $km^2$ study plot, in southern Nevada had parts of the cactus species (*Opuntia basilaris* ) in them (Esque 1987). *Opuntia basilaris* was also in the diet during a drought year at Ivanpah Valley, California (Turner et al. 1984). This cactus occurs at the Littlefield Site where it was eaten by tortoises, but it does not occur at the City Creek Site. Other species of cactus were consumed at both the City Creek Site and the Littlefield Site, but rarely.

Another cactus, *O. englemannii*, is eaten by tortoises where it occurs in Sonoran Desert habitats, in Arizona. Here, tortoises consume the ripened fruits of the cactus. Also, *O. englemannii* fruits may be eaten in abundance by individual tortoises. Based on a large sample size, however, Van Devender et al. (1993) reported that the role of *O. englemannii* in tortoise diets is generally overstated. Cacti did not play an important role in tortoise diets at the Littlefield Site and the City Creek Site in 1989 - 1992. Cactus are a persistent food resource that tortoises can exploit when other plants are unavailable. However, other tortoise species, such as the giant tortoises (*Geochelone elephantopus*) of the Galapagos Islands, are known to depend on *Opuntia* species for a large proportion of their diets (Cayot 1987).

Perennial Grasses in the Diet. Perennial grasses are regularly eaten by *Gopherus polyphemus* in the southeastern U.S. (McDonald and Mushinsky 1988). Perennial grasses also occur in desert tortoise diets (Turner et al. 1984, and Van Devender 1993), but they did not represent a large proportion of diet of tortoises during this study. Perennial grasses are patchy in distribution in the

Mojave Desert, and they are locally abundant at the Littlefield Site. In contrast, the patches are smaller and more discrete at the City Creek Site. Growth of grasses such as *Hilaria rigida* and *Sporobolus flexuosus* are dependent upon summer rains, and thus were not frequently observed in diets during the spring feeding periods. However, perennial grasses can persist over years and may be a different type of resource than the ephemeral winter/spring annual species which occur erratically. Tortoises can locate and use persistent resources such as drinking sites, and wintering dens repeatedly (Medica et al. 1980, Bury et al. *in press)*. If repeated use of persistent resources is possible I hypothesize that recollection could prompt the tortoises to use perennial food resources differently than the way they use annual vegetation. Although perennial grasses did not comprise a large proportion of the diets of desert tortoises during my study, they may be a resource with important value to tortoises over the long term.

Feces and Other Materials in Tortoise Diets. Consumption of feces (coprophagy) is thought to have a beneficial function in the diets of some herbivorous reptiles. For example, hatchling herbivorous iguanas inoculate themselves with cellulytic microorganisms by eating the feces of conspecifics (Troyer 1982). Coprophagy also may play a role in maintaining gut flora of young tortoises (Morafka *in press*). Additionally, the feces of predators such as the kit fox and coyote often contain bone fragments and other materials that could satisfy nutritional needs of tortoises ( Esque and Peters, *in press*). Feces of tortoises can be rich in protein and vitamins due to an abundance of microorganisms and dead erythrocytes. Recent studies by McArthur and Sanderson (1992, *in review*) reported that cattle feces at the Littlefield Site and the City Creek Site had a high proportion of undigested fiber in comparison to

known food plants. Thus, they considered cattle feces poor material for tortoises to feed upon; however, this conclusion neglects the value of proteins, vitamins and water in the feces.

Does Diet Selection Occur?. Diet selection for some plant species occurred in desert tortoise diets at the City Creek Site and the Littlefield Site. Some species were preferred, while other species were avoided. However, the underlying mechanisms for diet choice have yet to be explained. For example, why is it that certain species were avoided in some years, while preferred in other years? In the following paragraphs, I explore several hypotheses explaining diet selection in tortoises.

There was strong diet selection for some annual plant species at the City Creek Site and the Littlefield Site. However, there was not a strong pattern of selection for any group of plant species (i.e. exotics or natives) at either site among years. Instead, a single species could be preferred, avoided, or eaten at random with respect to availability during consecutive years. The patterns were also not consistent among sites within a single year.

My evidence for diet selection is corroborated by work on other herbivorous reptiles. Diet selection has been reported for other herbivorous reptiles: *Conolophus pallidus* (Christian et al. 1984), *Iguana iguana* (Troyer 1984a), *Geochelone carbonaria* and *Geochelone denticulata* (Moskovits 1985), and *Gopherus polyphemus* (MacDonald and Mushinsky 1988).

Selection of Exotics By Tortoises. Non-native (exotic) plant species represented a large proportion of the diet of desert tortoises in my study. Exotic annual

plants such as *Erodium cicutarium*, *Bromus spp.*, and *Schismus barbatus* were preferred, avoided, and used randomly, but their selection indices were different at each year and at each location. By itself, the selection for exotic species says nothing about the relative value of these plant species in the diet of desert tortoises. For example, it is possible that tortoises prefer plant species that are not particularly beneficial for them. Alternatively, tortoise selection for exotics may be nutritionally important. Initial results of nutritional analyses indicate that exotics may generally provide many of the nutrients available in native desert annuals (McArthur and Sanderson *in review*). Due to uncertainty about the nutritional value of exotics, however, interpretation of diet selection for these plant species should be viewed as tentative. Also, management decisions about the role of plants for tortoises should also be conservative until further data are available. Managers should be careful in basing land management practices on whether or not tortoises prefer or avoid exotic plant species until further experiments can be completed.

Analysis of $\alpha$ – Preference Values Analyzes Species in the Middle of a Broader Spectrum of Selection. Is the $\alpha$-preference method really an analysis of diet selection or more accurately an analysis of relative preference? The $\alpha$-preference analysis of diet selection relies upon analyzing the mean alpha preference values of plant species as a measure of diet selection. This is a beneficial technique because it allows departure from anecdotal evidence for diet preferences and to test hypotheses. However, there are limitations to this technique. After testing hypotheses it is possible to return to the data sets and learn more than by the test itself. For example, the $\alpha$-preference method is limited because it can only be used to analyze diet selection for relatively abundant species both in the diet and in the habitat at large. To compare diet

preference among years for the subset of species common to all analyses among years, we are limited to analyzing about five species of the 30 or so that may have been eaten by tortoises each year. These five species occur in the middle of a spectrum of species that were avoided, preferred or eaten at random relative to availability. Two classes of species cannot even be considered at all using the $\alpha$-preference method: (1) those species that were abundant in the habitat, but were rarely eaten when compared to the species in the $\alpha$-preference analysis; and (2) those species that were extremely rare in the habitat, but were usually eaten in their entirety when tortoises encountered them in certain phenological stages. However, these classes of rarity (availability and use) do not require statistics for interpretation.

Plant Species That Were Too Rare in the Tortoise Diets to Test for Selection. Several plant species were most clearly avoided: these species were abundant in the habitat, but were never eaten by tortoises. However, there are no quantitative data available for hypothesis testing. Perennial plants were avoided by tortoises and were so rare in the diet that they were eliminated from analyses. No perennial species was abundant enough in the diet to be included in among-years analyses. There were also several species of annuals that were almost always avoided by tortoises: *Eriastrum eremicum*, *Monoptilon bellioides*, *Eriogonum thomasii*, and *Festuca octaflora*. These species represent the extreme end of the avoidance spectrum. There may be many species between these avoided species and those species that are highly preferred. Possibly it is easier to detect strongly avoided than strongly preferred plants, because the strongly avoided plant species are abundant in the habitat (especially over the course of a study several years in length). In contrast, strongly preferred plant species that are rare in the habitat will be inherently difficult to detect. It is

difficult to find them during random searches, and to compound the difficulty, we can only sample a subset of tortoises diets through observation. It is difficult to observe tortoises consuming all of the plants that are rare in their diets.

Plant Species That Were Too Rare to be Included in Selection Analyses. Some plant species were so rare that they were not detected on vegetation transects. However, tortoises were able to find some of those species because abundant tracks of tortoises led us to sites where individual plants of single species were repeatedly devoured by desert tortoises. These species appear to be highly preferred, perhaps even more than the species included in the quantitative analysis of selection. However, our observations that some plant species were rarely recorded in vegetation samples but appeared to be preferred food items by tortoises could also be partially explained by sampling error. If plants reached anthesis either prior to, or subsequent to our vegetation sampling, then those species may have been absent from our vegetation surveys. For example, *Androstephium breviflorum* apparently was eaten by tortoises more frequently than it was found on vegetation transects. However, *A. breviflorum* blooms early, and when it dies, it is almost indistinguishable from litter; thus it was probably mostly missed in the vegetation sampling. Similarly, *Euphorbia parryi* blooms relatively late in Dune subhabitat, and it too could have been missed because it bloomed primarily after our vegetation sampling. However, there are plant species that simply are missed due to their rarity. *Oenothera pallida* is an annual species with a woody caudex that grows throughout our spring sampling periods. However, in most years it is so rare that it never is counted in vegetation estimates. Still, tortoises find this species consistently and devour it.

Why Are Plants Avoided or Preferred?. Causative factors of diet selection are difficult to assess. It has been hypothesized that plants are selected on the basis of several factors: energetic or nutritive qualities, the presence of secondary compounds, morphological adaptations that deter or promote herbivory or simply palatability. Some plant species, such as *Eriastrum eremicum,* were always avoided. E. *eremicum* has an acrid smell which may indicate the presence of plant secondary compounds that could deter herbivores. Thus, it may be easier to explain avoidance for some species than it is to explain preference for others.

No preference for certain food items appeared to be as strong as some avoidances. Additionally, tortoises switched their preferences for plant species. To better understand the causative factors for diet preference and/or avoidance, we need more knowledge of the intricacies of nutrition and energetics of both the plants and animals. For example, we do not understand nutrition and energetics of any wild organism well enough to conclude about the cause of diet selection.

Comparison of Diet Selection Along Foraging Routes to the Entire Habitat. The availability of food species along feeding routes showed no strong correlation to the availability of food plants on random transects throughout the study. This suggests that tortoises did not choose locations to feed that were different from random selection. However, certain plant species were selected from among all plants available along the feeding routes.

What Drives Diet Selection?. Hindgut fermentation of structural carbohydrates is a means to acquire energy in herbivorous reptiles (Nagy 1977, Bjorndahl 1979,

Troyer 1984b). The fermentation is accomplished through a symbiotic relationship with microorganisms in specialized compartments of the gut. Herbivores consume a diet containing fibrous vegetation (high in lignin and cellulose), and the microorganisms ferment the fiber into volatile fatty acids which can be used as an energy source by the herbivore. Troyer (1984) reported that green iguanas select leaves containing the highest fiber and protein, i.e. they selected classes of leaves to eat from a single tree for nutritional quality. Further, younger iguanas selected diets different from older animals. Apparently, the 'strategy' for diet selection was to choose a diet that meets energy and protein demands. Alternatives to the hypothesis that tortoises select species on the basis of nutritional quality include: (1) balancing the diet to avoid or nullify plant secondary compounds; (2) selecting plant species purely in relation to availability.

The gopher tortoise, *Gopherus polyphemus*, has hindgut fermentation to gain some of its required energy from ingestion of fiber in the diet (Bjorndahl 1987). Diet selection also has been reported for *G. polyphemus* (MacDonald and Mushinsky 1988). Possibly, the individual species of annual plant is less important in diet selection than nutritional content in a suite of plant species. Tortoises could select diet based on acquiring basic nutrients regardless of the plant species in which those nutrients occur.

Small Sample Sizes Can Affect Hypothesis Testing. Small samples can result in too few degrees of freedom to allow powerful statistical analyses. In this study there is huge variability of tortoise diets and preference values even though sample sizes were large.Small samples also may not allow generalizations about entire tortoise populations.

Studies of short duration and small sample sizes may not accurately reflect the pattern of diet selection for the population.

# CONCLUSIONS

## *The Diets of Desert Tortoises in the Northeastern Mojave Desert*

Observation of desert tortoises feeding was a successful means to determine tortoise diets in a non-destructive manner. Desert tortoise diets in the northeast Mojave Desert included 79 plant species at the City Creek Site, and 32 species at the Littlefield Site. Collectively, the tortoises were observed to eat about 50% of the species available at the City Creek Site, and the Littlefield Site although no individual tortoise took bites from that high a percentage of available species. The numbers of species in the diets of tortoises increased proportionally with the number of species available in the habitats for a given year which indicates that tortoises varied their diets in response to the availability of species. The numbers of plant species observed in desert tortoise diets increased during each successive year of research at the City Creek Site and the Littlefield Site. If observed long enough, tortoises probably sample everything that is available in their habitats. However, tortoise diets were dominated by annual plants. In the northeast Mojave Desert, woody perennial plants did not constitute a substantial proportion of tortoise diets. In relatively few cases, plants such as *Krameria* may be important in the diets of tortoises. However, perennials rarely constitute a substantial proportion of spring tortoise diets in the northeast Mojave Desert. On the basis of the number of bites that were observed, tortoises ate a large number of plant species. But only a few

species made up the majority of diets. Each year several of the species that dominated diets were exotic species.

Exotic species such as *Bromus rubens*, *B. tectorum*, *Schismus barbatus*, and *Erodium cicutarium* were important in diets of tortoises, because those species individually comprised a large proportion of diets every year. However, exotic species are also abundant in the habitats. As the number of species available to tortoises per year increased, the percentage of bites of exotic species in diets decreased. However, the occurrence of exotics in the diets of tortoises was not dependent upon increased biomass production of exotics. Exotic plants appeared to be important in tortoise diets because these plants were ubiquitous and abundant. However, native species were also important to tortoises. For example, *Plantago spp.* were the most abundant food item in the diets of tortoises at the Littlefield Site in 1991.

The Relative Proportions of Annual Forbs to Grasses in the Diets: The relative proportion of grasses in the diets of desert tortoises was proportional to the biomass production of annual grasses among years. The relative proportion of grasses to forbs in tortoise diets also had a seasonal pattern. There were relatively more forbs in the diets of desert tortoises early in the spring, and there were more grasses in the diets late in the spring. This pattern is probably due to the fact that forb species dry up and blow away whereas grass species remain intact in the habitat longer than forb species.

### *Diet Selection in the Northeast Mojave Desert*

Observing desert tortoises forage was a successful means to quantify diet selection. Statistical analyses provided new information about diet selection of desert tortoises. Tortoises were observed to make a substantial investment in acquisition of certain food items, indicated by the proportion of bites taken. When these plants were eaten with greater or lesser frequency than other species with respect to their relative abundance, they were "selected" (meaning that they were either preferred or avoided).

Analysis of among-year comparisons of diet selection required that only species that were common to all years be included. Plant species were required to be abundant in the habitat and abundantly used by tortoises. There were five species included in among-year comparisons at City Creek, and four species analyzed at the Littlefield Site. Within-year analyses did not require species prevalence in all years, so in some years it was possible to analyze selection for more than twice as many species as among-year comparisons.

Even though some plants were always prevalent in desert tortoise diets, on the basis of the number of bites eaten, there was not a single species that was *always* selected among-years or among-sites. The absence of a strong pattern of selection for a single species may help to elucidate one prediction of diet selection. The nutrition of annual plants does not fluctuate very much from year to year. Therefore, if the diet of tortoises does vary much each year, nutritional quality of plant species is likely not driving selection. Other measurable variables including biomass production and dispersion of plant species.

Rare Plants in the Diets of Desert Tortoises The majority of plant species in the diets of desert tortoises could not be included in selection analyses because they were either too rare in the habitat or too rare in the diets of tortoises. Even though woody plant selection could not be quantified, they were abundant in the habitat but absent in tortoise diets. There were also several annual plant species that were abundant in the habitat, but too rare in the diet to be included in selection analyses.

Plants that were rare in the habitat were predisposed for rarity in the diet. However, some plant species did appear to be preferred based on anecdotal information. Further investigation into the selection of rare species might be important to include in experiments where those plants can be located

Biomass Production and Dispersion in Relation to Diet Selection If diet selection is not driven by the nutrition of plant species, could plants be preferred or avoided relative to the ability of tortoises to locate those plants. For example, biomass production and dispersion could both affect the ability of tortoises to find and select those species. However, diet selection did not depend on biomass production or dispersion of plant species in the habitats among years or within sites.

Diet Selection for Exotic Plant Species Exotic annual plants were preferred species, avoided or eaten at random when alpha preference values were compared among years. Exotic species have an advantage over some other species because they are usually abundant, and thus almost always occurred in selection analyses. Tortoises select and avoid a few species of plants, and apparently feed at random on several other species.

### *Habitat Characteristics May Influence Behavior*

The number of plant species and biomass production differed among the two sites (the City Creek, and the Littlefield Sites). Tortoises spent a smaller proportion of feeding observations, and time they were observed feeding at the City Creek Site than the Littlefield Site. Average biomass production for entire sites was always less at the City Creek Site than at the Littlefield Site. The number of plant species available for tortoises to feed upon was always greater at the City Creek Site. Tortoises also spent different lengths of time (seasons) feeding at different sites. Tortoises at the City Creek Site fed later into the summer season than tortoises at the Littlefield Site.

### *Results May Vary Due to Technique*

Low sample sizes of observations can result in an under representation of the number of species observed in the diets of tortoises. Analysis of data from any one (but only one) year of this study, would have led to entirely different conclusions about diet selection in desert tortoises. There was a diversity of responses to diet selection among several years and more than one site; thus foraging and nutrition studies should be conducted over several years.

### *Future Research Directions*

The food resources available to the herbivorous desert tortoise can be highly variable within and among seasons. More information is needed to understand the nutritional ecology of desert tortoises. It will be necessary to observe tortoises eating throughout the activity season, at other sites (e.g. in Sonoran

Desert), and conduct laboratory studies on diet assimilation prior to understanding the causes of the patterns I have described. This study makes the first step toward understanding the deterministic conditions that govern characteristics of diet and diet selection of tortoises at two sites in the northeast Mojave desert.

Additional research emphases that might elucidate the mechanisms of diet selection and nutrition include:

1) Consideration of variability of diet selection among individual tortoises.
2) Controlled selection experiments using captive or wild tortoises on plant species that are too rare to test in wild tortoises
3) Growth and physiology experiments to determine the role of quantity versus quality of food resources.
4) Importance of diet supplementation of soils, stones, and bones.

5) Matching of data and theory (e.g., optimal foraging theory, and optimal digestion theory) to explain the nutritional ecology of desert tortoises as a more predictive science.

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Appendix I. Descriptive statistics for desert tortoise feeding observations (1990 - 1992) at the City Creek Site, and the Littlefield Site.

Appendix I A. Descriptive statistics for desert tortoise feeding observations at the City Creek Site in 1990. Only data for April, May, and June were used in diet selection analyses.

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 22-Apr-90 | 393 | F | Dune | 1 | 117 | 10 | 1 |
| 23-May-90 | 393 | | Dune | 25 | 320 | ** | 3 |
| 19-May-90 | 1150 | F | Dune | 2 | 28 | ** | 1 |
| 19-May-90 | 1150 | | Blackbrush | 73 | 72 | ** | 6 |
| 15-Jun-90 | 1150 | | Blackbrush | 37 | 266 | 50 | 3 |
| 20-Apr-90 | 1150 | | Blackbrush | 10 | 15 | 10 | 1 |
| 22-May-90 | 1150 | | Transition | 25 | 125 | ** | 5 |
| 5-May-90 | 1150 | | Transition | 25 | 45 | ** | 2 |
| 22-Apr-90 | 1190 | F | Dune | 40 | 74 | ** | 3 |
| 23-May-90 | 1190 | | Dune | 90 | 270 | 120 | 8 |
| 27-May-90 | 1190 | | Dune | 127 | 218 | 92 | 7 |
| 7-Jun-90 | 1190 | | Dune | 2 | 18 | 2 | 1 |
| 7-Jun-90 | 1190 | | Rocky | 88 | 217 | 55 | 12 |
| 8-May-90 | 1190 | | Transition | 15 | 95 | 22 | 5 |
| 15-May-90 | 1190 | | Transition | 1 | 360 | 10 | 1 |
| 29-May-90 | 1190 | | Transition | 115 | 405 | 50 | 8 |
| 4-Jun-90 | 1198 | F | Dune | 3 | 199 | 21 | 2 |
| 9-Jun-90 | 1198 | | Dune | 15 | 93 | 26 | 3 |
| 26-May-90 | 1198 | | Rocky | 38 | 218 | ** | 3 |
| 30-May-90 | 1198 | | Rocky | 52 | 90 | 25 | 19 |
| 2-Jun-90 | 1198 | | Rocky | 56 | 115 | 15 | 10 |
| 9-Jun-90 | 1198 | | Rocky | 4 | 34 | 13 | 2 |
| 13-Jun-90 | 1198 | | Rocky | 46 | 212 | 20 | 5 |

** missing data

Appendix I A. (Continued)

| Date | Tortoise Identification | Sex | Habitat Type | Time Foraging (minutes) | Time Total (minutes) | Distance Travelled (meters) | Number of Patches |
|---|---|---|---|---|---|---|---|
| 20-Jun-90 | 1198 | F | Rocky | 46 | 225 | 13 | 13 |
| 9-Jun-90 | 1198 | | Blackbrush | 63 | 63 | 53 | 18 |
| 6-May-90 | 1198 | | Transition | 53 | 71 | ** | 2 |
| 6-May-90 | 1198 | | Transition | 34 | 45 | 100 | 3 |
| 21-Jun-90 | 1208 | F | Blackbrush | 26 | 255 | 45 | 9 |
| 5-Jun-90 | 1208 | | Transition | 62 | 245 | 100 | 3 |
| 21-May-90 | 1244 | F | Rocky | 93 | 154 | 70 | 21 |
| 6-Jun-90 | 1244 | | Rocky | 96 | 151 | ** | 11 |
| 14-Jun-90 | 1244 | | Rocky | 1 | 79 | 71 | 1 |
| 30-May-90 | 1244 | | Blackbrush | 17 | 120 | 4 | 3 |
| 2-Jun-90 | 1244 | | Blackbrush | 120 | 227 | 100 | 11 |
| 9-Jun-90 | 1244 | | Blackbrush | 131 | 170 | 200 | 14 |
| 14-May-90 | 1244 | | Transition | 71 | 151 | 14 | 5 |
| 8-Apr-90 | 1281 | F | Dune | 21 | 23 | 0 | 6 |
| 25-Apr-90 | 1281 | | Dune | 82 | 150 | 44 | 14 |
| 5-May-90 | 1281 | | Dune | 59 | 71 | 40 | 19 |
| 7-May-90 | 1281 | | Dune | 14 | 93 | 18 | 8 |
| 19-May-90 | 1281 | | Dune | 42 | 109 | 60 | 5 |
| 6-Jun-90 | 1281 | | Dune | 80 | 80 | ** | 9 |
| 20-Jun-90 | 1281 | | Dune | 25 | 280 | 43 | 2 |
| 22-May-90 | 1281 | | Rocky | 10 | 23 | 20 | 4 |
| 13-Jun-90 | 1281 | | Rocky | 6 | 300 | 11 | 4 |
| 6-Jun-90 | 1281 | | Blackbrush | 12 | 56 | ** | 3 |
| 19-Apr-90 | 1281 | | Transition | 30 | 40 | 25 | 10 |

** missing data

Appendix I A. (Continued)

| Date | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 26-May-90 | 1281 | F | Transition | 50 | 100 | 120 | 22 |
| 6-Jun-90 | 1281 |  | Transition | 21 | 21 | ** | 1 |
| 8-Jun-90 | 1281 |  | Transition | 105 | 175 | 160.9 | 6 |
| 27-Jun-90 | 1281 |  | Transition | 101 | 117 | 35 | 20 |
| 6-May-90 | 1282 | F | Dune | 147 | 231 | 185 | 27 |
| 23-May-90 | 1282 |  | Dune | 28 | 126 | 302 | 3 |
| 7-Jun-90 | 1282 |  | Rocky | 88 | 176 | 88 | 8 |
| 12-Jun-90 | 1282 |  | Rocky | 8 | 203 | 26 | 3 |
| 31-May-90 | 1282 |  | Blackbrush | 175 | 340 | 75 | 17 |
| 11-Jun-90 | 1282 |  | Blackbrush | 12 | 256 | 20 | 2 |
| 12-Jun-90 | 1282 |  | Blackbrush | 35 | 34 | 33 | 21 |
| 21-Jun-90 | 1282 |  | Blackbrush | 177 | 240 | ** | 26 |
| 20-May-90 | 1282 |  | Transition | 138 | 138 | ** | 5 |
| 27-May-90 | 1282 |  | Transition | 113 | 169 | 50 | 3 |
| 5-Jun-90 | 1282 |  | Transition | 48 | 80 | 16 | 4 |
| 27-Jun-90 | Unknown |  | Rocky | 67 | 67 | ** | 4 |

** missing data

Appendix IB. Descriptive statistics for desert tortoise feeding observations at the City Creek Site in 1991. Only data for April, May, and June were used in diet selection analyses.

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 15-Jul-91 | 378 | M | Transition | 13 | 26 | 7 | 3 |
| 30-Apr-91 | 393 | F | Blackbrush | 85 | 397 | ** | 14 |
| 21-Jun-91 | 462 | M | Blackbrush | 6 | 6 | 12 | 4 |
| 21-Jun-91 | 462 | | Transition | 25 | 25 | 10 | 3 |
| 21-Jun-91 | 462 | | Rocky | 11 | 141 | 22 | 3 |
| 26-Jun-91 | 462 | | Transition | 4 | 4 | 1 | 1 |
| 19-Jun-91 | 463 | M | Blackbrush | 39 | 122 | 3 | 3 |
| 19-Jun-91 | 463 | | Transition | 10 | 54 | 70 | 3 |
| 19-Jun-91 | 463 | | Rocky | 23 | 30 | 14 | 2 |
| 21-Jun-91 | 463 | | Rocky | 31 | 52 | 26 | 6 |
| 21-Jun-91 | 463 | | Blackbrush | 7 | 205 | 4 | 2 |
| 20-Jun-91 | 1144 | M | Rocky | 3 | 143 | 14 | 1 |
| 20-Jun-91 | 1144 | | Transition | 42 | 76 | 27 | 5 |
| 21-Jun-91 | 1144 | | Blackbrush | 124 | 170 | 70 | 15 |
| 18-Jun-91 | 1150 | F | Blackbrush | 57 | 161 | ** | 9 |
| 26-Jun-91 | 1150 | | Blackbrush | 16 | 205 | 90 | 8 |
| 26-Jun-91 | 1150 | | Transition | 65 | 70 | 45 | 30 |
| 17-Jun-91 | 1150 | | Blackbrush | 30 | 170 | 24 | 9 |
| 12-Jun-91 | 1150 | | Blackbrush | 74 | 234 | 50 | 33 |
| 14-Jun-91 | 1150 | | Blackbrush | 30 | 199 | 72 | 8 |
| 18-Jun-91 | 1150 | | Blackbrush | 10 | 138 | 12 | 5 |
| 14-Jun-91 | 1155 | M | Transition | 83 | 166 | 70 | 11 |
| 15-Jun-91 | 1198 | F | ROCKY | 39 | 194 | 6 | 3 |

** missing data

Appendix IB. (Continued)

| Date | Tortoise Identification | Sex | Habitat Type | Time Foraging (minutes) | Time Total (minutes) | Distance Travelled (meters) | Number of Patches |
|---|---|---|---|---|---|---|---|
| 17-Jun-91 | 1198 | F | Blackbrush | 26 | 145 | 10 | 5 |
| 24-Jun-91 | 1198 | | Rocky | 57 | 212 | 24 | 11 |
| 26-Jun-91 | 1198 | | Dune | 8 | 20 | 5 | 1 |
| 6-Aug-91 | 1208 | F | Rocky | 34 | 34 | 47 | 3 |
| 6-Aug-91 | 1208 | | Blackbrush | 7 | 138 | 49 | 4 |
| 6-Aug-91 | 1208 | | Transition | 45 | 123 | 146 | 26 |
| 12-Jul-91 | 1208 | | Dune | 89 | 262 | 6 | 6 |
| 15-Jul-91 | 1208 | | Dune | 25 | 230 | 8 | 5 |
| 22-Jul-91 | 1208 | | Dune | 30 | 250 | 9 | 6 |
| 27-Jun-91 | 1208 | | Transition | 40 | 265 | 10 | 7 |
| 13-May-91 | 1208 | | DUNE | 26 | 240 | ** | 3 |
| 9-Sep-91 | 1216 | M | Rocky | 34 | 305 | 25 | 5 |
| 23-Jul-91 | 1234 | F | Rocky | 69 | 280 | 15 | 7 |
| 13-Jun-91 | 1234 | | Dune | 70 | 115 | 42 | 11 |
| 17-Jun-91 | 1234 | | Dune | 47 | 220 | 22 | 5 |
| 5-Jun-91 | 1234 | | Blackbrush | 59 | 225 | 17 | 7 |
| 13-May-91 | 1234 | | Dune | 21 | 360 | 20 | 11 |
| 22-Apr-91 | 1244 | F | Rocky | 2 | 75 | ** | 1 |
| 22-Apr-91 | 1244 | | Blackbrush | 38 | 210 | ** | 13 |
| 12-Jun-91 | 1244 | | Blackbrush | 15 | 165 | 20 | 5 |
| 29-May-91 | 1244 | | Rocky | 60 | 105 | 12 | 8 |
| 9-May-91 | 1244 | | Blackbrush | 56 | 295 | 65 | 14 |
| 14-Jun-91 | 1281 | F | Dune | 30 | 95 | 26 | 8 |
| 25-Jun-91 | 1281 | | Dune | 70 | 140 | 22 | 11 |

** missing data

Appendix IB. (Continued)

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 1-May-91 | 1281 | F | Transition | 49 | 153 | 17 | 13 |
| 1-May-91 | 1281 | | Dune | 6 | 69 | 12 | 1 |
| 9-Apr-91 | 1282 | M | Blackbrush | 68 | 258 | 20 | 7 |
| 13-Jun-91 | 1282 | | Blackbrush | 61 | 155 | 11 | 6 |
| 17-Jun-91 | 1282 | | Dune | 85 | 254 | 83 | 15 |
| 27-Jun-91 | 1282 | | Transition | 78 | 308 | 49 | 8 |
| 27-Jun-91 | 1282 | | Dune | 24 | 24 | 14 | 2 |
| 24-May-91 | 1282 | | Transition | 85 | 134 | 40 | 17 |
| 24-May-91 | 1282 | | Dune | 52 | 53 | 38 | 13 |
| 20-Jun-91 | Unknown† | | Blackbrush | 23 | 87 | 20 | 4 |
| 20-Jun-91 | Unknown | | Rocky | 8 | 148 | 14 | 2 |
| 13-May-91 | Unmarked | | Rocky | 6 | 6 | 3 | 2 |
| 13-May-91 | Unmarked | | Blackbrush | 71 | 164 | 52 | 16 |

** missing data

† Unknown radioed tortoise

Appendix IC. Descriptive statistics for desert tortoise feeding observations at the City Creek Site in 1992. Only data for April, May, and June were used in diet selection analyses.

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 10-Jun-92 | 378 | M | Rocky | 1 | 236 | 1 | 1 |
| 22-Apr-92 | 393 | F | Dune | 90 | 230 | ** | 0 |
| 6-May-92 | 393 | | Dune | 1 | 200 | 7 | 1 |
| 20-May-92 | 393 | | Dune | 323 | 329 | 143 | 29 |
| 2-Jun-92 | 393 | | Dune | 67 | 128 | ** | 10 |
| 22-Jun-92 | 393 | | Dune | 44 | 93 | 25 | 7 |
| 17-Jun-92 | 393 | | Blackbrush | 0 | 225 | 0 | 0 |
| 5-Jul-92 | 465 | M | Blackbrush | 0 | 280 | 0 | 0 |
| 17-Jun-92 | 465 | | Rocky | 0 | 237 | 0 | 0 |
| 24-Jun-92 | 465 | | Rocky | 0 | 120 | 0 | 0 |
| 4-Jun-92 | 465 | | Blackbrush | 5 | 210 | 5 | 1 |
| 18-May-92 | 466 | M | Blackbrush | 78 | 170 | 46 | 10 |
| 18-May-92 | 466 | | Rocky | 7 | 10 | 58 | 5 |
| 8-Jun-92 | 592 | F | Dune | 0 | 258 | 0 | 0 |
| 5-may-92 | 592 | | Rocky | 0 | 115 | 0.5 | 0 |
| 25-Jun-92 | 592 | | Transition | 50 | 245 | 23 | 10 |
| 4-Jun-92 | 593 | F | Dune | 0 | 284 | 0 | 0 |
| 8-Jun-92 | 593 | | Dune | 0 | 280 | 0 | 0 |
| 23-Jun-92 | 593 | | Rocky | 0 | 255 | 0 | 0 |
| 26-Jun-92 | 593 | | Rocky | 0 | 230 | 0 | 0 |
| 1-Jul-92 | 593 | | Transition | 0 | 218 | 0 | 0 |
| 3-Apr-92 | 1117 | F | Blackbrush | 3 | 255 | 2 | 1 |
| 20-Apr-92 | 1117 | | Blackbrush | 0 | 250 | 35 | 0 |

** missing data

Appendix I C. (continued)

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 29-Jun-92 | 1117 | F | Blackbrush | 17 | 125 | ** | ** |
| 2-Jun-92 | 1117 | | Rocky | 0 | 215 | 0 | 0 |
| 7-Jun-92 | 1117 | | Rocky | 0 | 198 | 0 | 0 |
| 19-Jun-92 | 1117 | | Blackbrush | 165 | 165 | 144.5 | 8 |
| 23-Jun-92 | 1117 | | Blackbrush | 42 | 212 | 69 | 4 |
| 29-Jun-92 | 1117 | | Blackbrush | 17 | 125 | ** | 6 |
| 7-Jul-92 | 1117 | | Transition | 0 | 255 | 0 | 0 |
| 18-May-92 | 1126 | M | Blackbrush | 0 | 162 | 0 | 0 |
| 8-Jun-92 | 1126 | | Blackbrush | 0 | 170 | 0 | 0 |
| 29-Jun-92 | 1126 | | Rocky | 120 | 165 | 249 | 28 |
| 1-Jul-92 | 1126 | | Rocky | 87 | 87 | 32 | 6 |
| 10-Jun-92 | 1126 | | Blackbrush | 180 | 197 | 424 | 32 |
| 23-Jun-92 | 1126 | | Blackbrush | 105 | 105 | 77 | 10 |
| 4-Jun-92 | 1126 | | Transition | 87 | 155 | 40 | 18 |
| 29-may-92 | 1126 | | Transition | 12 | 148 | 11 | 3 |
| 19-Jun-92 | 1130 | M | Rocky | 0 | 228 | 0 | 0 |
| 23-Jun-92 | 1130 | | Blackbrush | 30 | 196 | 65 | 7 |
| 10-Jun-92 | 1130 | | Transition | 0 | 225 | 0 | 0 |
| 23-Jun-92 | 1130 | | Transition | 20 | 14 | 41 | 3 |
| 2-Jun-92 | 1130 | | Transition | 0 | 210 | 0 | 0 |
| 23-Jun-92 | 1144 | M | Dune | 139 | 158 | 173 | 35 |
| 29-May-92 | 1144 | | Blackbrush | ** | 199 | 158 | ** |
| 25-jun-92 | 1144 | | Transition | 70 | 156 | ** | ** |
| 25-Jun-92 | 1144 | | Transition | 70 | 156 | ** | 25 |

** missing data

Appendix I C. (continued)

| Date | Tortoise Identification | Sex | Habitat Type | Time Foraging (minutes) | Time Total (minutes) | Distance Travelled (meters) | Number of Patches |
|---|---|---|---|---|---|---|---|
| 20-Apr-92 | 1150 | F | Dune | 155 | 185 | ** | 20 |
| 20-Apr-92 | 1150 | | Blackbrush | 48 | 152 | 204 | 8 |
| 4-May-92 | 1150 | | Blackbrush | 28 | 28 | 16 | 5 |
| 4-May-92 | 1150 | | Rocky | 42 | 80 | 68 | 16 |
| 13-May-92 | 1150 | | Rocky | 0 | 75 | 0 | 0 |
| 25-Jun-92 | 1150 | | Rocky | 0 | 43 | 70 | 0 |
| 10-Jun-92 | 1150 | | Blackbrush | 91 | 223 | 252 | 13 |
| 19-Jun-92 | 1150 | | Blackbrush | 6 | 222 | 40 | 2 |
| 25-Jun-92 | 1150 | | Blackbrush | 40 | 57 | 155 | 19 |
| 4-May-92 | 1150 | | Transition | 14 | 14 | 23 | 11 |
| 2-Jul-92 | 1153 | F | Rocky | 0 | 217 | 0 | 0 |
| 2-Jun-92 | 1153 | | Transition | 172 | 208 | 49 | 14 |
| 25-Jun-92 | 1158 | ? | rocky | ** | ** | 74 | 1 |
| 13-May-92 | 1190 | F | Dune | 41 | 60 | 35 | 16 |
| 20-May-92 | 1190 | | Dune | 154 | 323 | 183 | 57 |
| 17-Jun-92 | 1190 | | Dune | 0 | 259 | 0 | 0 |
| 22-Jun-92 | 1190 | | Dune | 80 | 80 | 80 | 15 |
| 13-Jul-92 | 1190 | | Dune | 20 | 283 | 29 | ** |
| 22-Apr-92 | 1190 | | Blackbrush | 6 | 319 | ** | 1 |
| 6-Jul-92 | 1190 | | Blackbrush | 0 | 221 | 0 | 0 |
| 20-May-92 | 1190 | | Blackbrush | 0 | 25 | 24 | 0 |
| 24-Jun-92 | 1190 | | Rocky | 0 | 229 | 0 | 0 |
| 24-Jun-92 | 1190 | | Rocky | 0 | 229 | 0 | 0 |
| 2-Jun-92 | 1190 | | Transition | 116 | 135 | 229 | 64 |

** missing data

Appendix I C. (continued)

| Date | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 8-Jun-92 | 1190 | F | Transition | 85 | 210 | 145 | 24 |
| 13-May-92 | 1190 | | Transition | 15 | 43 | 35 | 28 |
| 20-MayY-92 | 1190 | | Transition | 6 | 11 | 19 | 4 |
| 8-Jun-92 | 1198 | F | Blackbrush | 20 | 315 | 121 | 5 |
| 29-May-92 | 1198 | | Rocky | 50 | 229 | 73 | 12 |
| 19-Jun-92 | 1198 | | Rocky | 14 | 172 | 1 | 1 |
| 24-Jun-92 | 1198 | | Rocky | 0 | 150 | 0 | 0 |
| 25-Jun-92 | 1198 | | Rocky | 0 | 210 | 0 | 0 |
| 13-May-92 | 1208 | F | Dune | 42 | 162 | 55 | 12 |
| 20-May-92 | 1208 | | Dune | 159 | 191 | ** | 31 |
| 17-Jun-92 | 1208 | | Dune | 0 | 285 | 0 | 0 |
| 24-Jun-92 | 1208 | | Dune | 0 | 251 | 0 | 0 |
| 7-Jul-92 | 1208 | | Blackbrush | 180 | 511 | 200 | ** |
| 4-Jun-92 | 1208 | | Transition | 87 | 127 | 93 | 23 |
| 22-Apr-92 | 1216 | M | Blackbrush | 22 | 310 | 141 | 11 |
| 6-May-92 | 1216 | | Blackbrush | 103 | 175 | 40 | 9 |
| 18-May-92 | 1216 | | Blackbrush | 0 | ** | 0 | 0 |
| 21-May-92 | 1216 | | Blackbrush | 0 | 92 | 0 | 0 |
| 6-Jul-92 | 1216 | | Blackbrush | 60 | 90 | 194 | 23 |
| 17-Jun-92 | 1216 | | Rocky | 0 | 189 | 0 | 0 |
| 22-Jun-92 | 1216 | | Blackbrush | 96 | 96 | 79 | 19 |
| 24-Jun-92 | 1216 | | Blackbrush | 30 | 125 | 19.75 | 8 |
| 29-May-92 | 1231 | F | Blackbrush | 0 | 222 | 0 | 0 |
| 4-Jun-92 | 1231 | | Blackbrush | 11 | 240 | 37 | 2 |

** missing data

Appendix I C. (continued)

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 8-Jun-92 | 1231 | F | Rocky | 0 | 237 | 0 | 0 |
| 10-Jun-92 | 1231 | | Rocky | 0 | 315 | 0 | 0 |
| 26-Jun-92 | 1231 | | Rocky | 0 | 228 | 0 | 0 |
| 23-Jun-92 | 1231 | | Transition | 0 | 191 | 0 | 0 |
| 20-May-92 | 1234 | F | Dune | 65 | 160 | ** | 12 |
| 8-Jun-92 | 1234 | | Dune | 81 | 220 | 215 | 18 |
| 2-Jul-92 | 1234 | | Blackbrush | 42 | 260 | 78 | 15 |
| 24-Jun-92 | 1234 | | Blackbrush | 0 | 240 | 0 | 0 |
| 4-Jun-92 | 1234 | | Transition | 105 | 177 | 378 | 33 |
| 18-May-92 | 1234 | | Dune | 61 | 199 | 109 | 19 |
| 3-Apr-92 | 1244 | F | Blackbrush | 0 | 70 | 0 | 0 |
| 12-May-92 | 1244 | | Blackbrush | 0 | 105 | 0 | 0 |
| 10-Jun-92 | 1244 | | Rocky | 47 | 188 | 23 | 11 |
| 25-Jun-92 | 1244 | | Rocky | 0 | 360 | 0 | 0 |
| 19-Jun-92 | 1244 | | Blackbrush | 85 | 109 | 109 | 19 |
| 23-Jun-92 | 1244 | | Blackbrush | 0 | 235 | 0 | 0 |
| 2-Jun-92 | 1244 | | Transition | 0 | 167 | 0 | 0 |
| 4-May-92 | 1281 | F | Dune | 0 | 165 | 0 | 0 |
| 3-Apr-92 | 1281 | | Transition | 0 | 90 | 1 | 0 |
| 20-May-92 | 1282 | F | Dune | * | * | 64 | 8 |
| 4-Jun-92 | 1282 | | Dune/Trans | 114 | 184 | 125 | 24 |
| 22-Apr-92 | 1282 | | Blackbrush | 150 | 208 | ** | ** |
| 24-May-92 | 1282 | | Transition | 2 | 227 | 6 | 2 |
| 22-Jun-92 | 1282 | | Transition | 22 | 85 | 14 | 2 |

** missing data

Appendix I C. (continued)

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 7-Jul-92 | 1282 | F | Transition | 0 | 382 | 0 | 0 |
| 23-Jun-92 | UNMARKED |  | Transition | 6 | 191 | 25 | 4 |
| 8-Jun-92 | UNMARKED |  | Blackbrush | 38 | 199 | 32 | 10 |

Appendix ID. Descriptive statistics for desert tortoise feeding observations at the Littlefield Site in 1990. Only data for April, May, and June were used in diet selection analyses.

| *Date* | *Tortoise identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 25-May-90 | 148.077 | F | LA | 5 | 284 | 50.2 | 2 |
| 21-May-90 | 148.123 | F | LA | 28 | 173 | 24 | 9 |
| 25-May-90 | 148.123 |  | LA | 20 | 165 | 18 | 4 |
| 25-May-90 | 148.123 |  | WASH | 54 | 63 | 42 | 3 |
| 13-Jun-90 | 148.179 | F | LA | 2 | 305 | 19 | 2 |
| 24-May-90 | 148.179 |  | LA | 27 | 122 | 52 | 4 |
| 5-Jun-90 | 148.179 |  | LAC | 4 | 205 | 92 | 3 |
| 13-Jun-90 | 148.224 | F | LAC | 70 | 249 | 75 | 4 |
| 14-Jun-90 | 148.224 |  | LAC | 80 | 170 | 122 | 6 |
| 21-May-90 | 148.224 |  | LAC | 30 | 199 | 4 | 2 |
| 5-Jun-90 | 148.224 |  | LACH | 22 | 63 | 78 | 5 |
| 25-May-90 | 148.228 | F | LAH | 48 | 119 | 148 | 6 |
| 30-May-90 | 148.228 |  | LA | 5 | 270 | 30 | 5 |
| 4-Jun-90 | 148.228 |  | LA | 21 | 221 | 160.9 | 15 |
| 4-May-90 | 148.525 | F | LA | 3 | 102 | 60 | 2 |
| 12-Jun-90 | 149.694 | F | LA | 39 | 187 | 160.9 | 5 |
| 24-May-90 | 149.694 |  | LA | 39 | 310 | 50 | 6 |
| 25-May-90 | 149.694 |  | LA | 6 | 131 | 45 | 1 |
| 4-Jun-90 | 149.694 |  | LA | 71 | 185 | 5 | 7 |
| 6-Jun-90 | 149.694 |  | LA | 39 | 255 | 38 | 12 |
| 10-May-90 | 203 | F | LA | 20 | 33 | 10 | 10 |
| 11-May-90 | 203 |  | LA | 68 | 232 | 16 | 11 |

** missing data

Appendix I E. Descriptive statistics for desert tortoise feeding observations at the Littlefield Site in 1991. Only data for April, May, and June were used in diet selection analyses.

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 8-May-91 | 207 | F | LAC | 87 | 314 | 13 | ** |
| 1-Jun-91 | 210 | F | LA | 18 | 300 | 6 | 31 |
| 14-Jun-91 | 210 |  | LAC | 99 | 219 | 26 | 55 |
| 8-Aug-91 | 224 | F | WASH | 12 | 20 | 10 | 15 |
| 8-Apr-91 | 280 | M | LA | 32 | 130 | 12 | 24 |
| 27-Aug-91 | 280 |  | LA | 63 | 188 | 35 | 215 |
| 18-Jun-91 | 280 |  | LA | 125 | 135 | 6 | 7 |
| 8-Aug-91 | H036 | M | LAH | 77 | 252 | 17 | 44 |
| 4-Jun-91 | H036 |  | LA | 59 | 223 | 27 | 36 |
| 25-Apr-91 | H042 | M | LA | 7 | 180 | 2 | ** |
| 10-Apr-91 | HO67 | F | LA | 232 | 439 | 27 | ** |
| 17-Apr-91 | H067 |  | LA | 58 | 340 | 16 | 35 |
| 22-Jul-91 | H067 |  | LA | 69 | 237 | 7 | 105 |
| 17-Jun-91 | H067 |  | LAH | 95 | 110 | 29 | 90 |
| 4-Jun-91 | H067 |  | WASH | 54 | 170 | 22 | 150 |
| 17-Jun-91 | H068 | M | LA | 41 | 49 | 29 | 64 |
| 28-May-91 | H068 |  | LA | 225 | 237 | 29 | 70 |
| 17-Apr-91 | H084 | F | LA | 8 | 360 | 4 | ** |
| 10-Jun-91 | H084 |  | LAC | 15 | 223 | 2 | 30 |
| 26-Aug-91 | S108 | F | LAH | 7 | 225 | 4 | 149 |
| 24-Jul-91 | S108 |  | LA | 9 | 244 | 1 | 26 |

** missing data

Appendix I E. (Continued).

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 23-Apr-91 | S131 | M | LA | 2 | 185 | 1 | 1 |
| 17-Jun-91 | S131 |  | LA | 18 | 166 | 3 | 11 |
| 17-Jun-91 | S156 | M | LA | 137 | 250 | 19 | 192 |
| 6-May-91 | S156 |  | LA | 68 | 415 | 23 | 22 |
| 10-Sep-91 | S156 |  | LA | 2 | 165 | 2 | 25 |

** missing data

Appendix I F. Descriptive statistics for desert tortoise feeding observations at the Littlefield Site in 1992. Only data for April, May, and June were used in diet selection analyses.

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 19-May-92 | 1.285 | F | LAH | 0 | 227 | 0 | 0 |
| 18-Jun-92 | 151.285 | | LAH | 0 | 165 | 0 | 0 |
| 3-Jun-92 | 151.285 | | LAH | 51 | 120 | 10 | 7 |
| 14-May-92 | 207 | F | LA | 37 | 260 | 145 | 13 |
| 5-Jun-92 | 207 | | LA | 40 | 192 | 20 | 8 |
| 21-Apr-92 | 207 | | LAC | 0 | 180 | 0 | 0 |
| 11-Jun-92 | 207 | | LA | 0 | 175 | 0 | 0 |
| 16-Jun-92 | 207 | | LA | 0 | 245 | 0 | 0 |
| 3-Jun-92 | 207 | | LA | 0 | 200 | 0 | 0 |
| 21-Apr-92 | 210 | F | LAC | 2 | 210 | 7 | ** |
| 5-Jun-92 | 250 | ? | LA | 73 | 146 | 241.5 | 6 |
| 9-Jun-92 | 250 | | LA | 30 | 214 | 15 | 4 |
| 10-Jul-92 | 250 | | LA | 0 | 234 | 0 | 0 |
| 16-Jun-92 | 250 | | LA | 0 | 185 | 0 | 0 |
| 27-May-92 | 250 | | LA | 0 | 0 | 0 | 0 |
| 14-Apr-92 | 250 | | Wash | 1 | 228 | 6 | 1 |
| 23-Apr-92 | 280 | M | LA | 37 | 164 | 20 | 9 |
| 19-May-92 | 280 | | LA | 163 | 285 | 246 | 53 |
| 3-Jun-92 | 280 | | LA | 85 | 85 | 77 | 32 |
| 11-Jun-92 | 280 | | LA | 0 | 164 | 0 | 0 |
| 16-Jun-92 | 280 | | LA | 0 | 165 | 0 | 0 |
| 22-Jun-92 | 280 | | LA | 0 | 225 | 0 | 0 |

** missing data

Appendix I F. (Continued)

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 9-Jun-92 | 289 | M | LA | 0 | 225 | 0 | 0 |
| 5-Jun-92 | 289 | | LA | 0 | 190 | 0 | 0 |
| 18-Jun-92 | 289 | | LA | 0 | 150 | 0 | 0 |
| 16-Jun-92 | 289 | | WASH | 0 | 142 | 0 | 0 |
| 13-Apr-92 | H036 | M | LA | 1 | 170 | 2.25 | 0 |
| 11-May-92 | H036 | | LA | 11 | 108 | ** | 3 |
| 18-Jun-92 | H036 | | LA | 0 | 214 | 0 | 0 |
| 28-May-92 | H036 | | LA | 0 | 194 | 0 | 0 |
| 1-Jun-92 | HO36 | | LA | 32 | 300 | 19 | ** |
| 3-Jun-92 | HO36 | | LA | 0 | 205 | 0 | 0 |
| 14-Apr-92 | H038 | M | LAC | 0 | 95 | 0 | 0 |
| 3-Jun-92 | H038 | | LA | 0 | 210 | 0 | 0 |
| 28-May-92 | H038 | | WASH | 0 | 180 | 0 | 0 |
| 19-Jun-92 | H038 | | WASH | 0 | 240 | 0 | 0 |
| 30-Jun-92 | H038 | | WASH* | 0 | 11 | 0 | 0 |
| 1-May-92 | H042 | M | LA | 0 | 15 | 0 | 0 |
| 16-Jun-92 | H042 | | LA | 0 | 201 | 0 | 0 |
| 1-Jun-92 | H042 | | LA | 0 | 245 | 0 | 0 |
| 5-Jun-92 | HO42 | | LA | 101 | 101 | 138 | 19 |
| 11-Jun-92 | HO42 | | LA | 0 | 217 | 0 | 0 |
| 5-Jun-92 | HO42 | | WASH | 6 | 6 | 15 | 1 |
| 11-Jun-92 | HO42 | | WASH | 0 | 217 | 0 | 0 |
| 13-Apr-92 | H067 | F | LA | 0 | 155 | 2 | 0 |
| 22-Apr-92 | H067 | | LA | 0 | 260 | ** | 0 |

** missing data

Appendix I F. (Continued)

| Date | Tortoise Identification | Sex | Habitat Type | Time Foraging (minutes) | Time Total (minutes) | Distance Travelled (meters) | Number of Patches |
|---|---|---|---|---|---|---|---|
| 1-may-92 | H067 | F | LA | 0 | 60 | 0 | 0 |
| 9-Jun-92 | H067 | | LA | 28 | 140 | 185 | 7 |
| 1-Jun-92 | H067 | | LA | 60 | 74 | 93 | 17 |
| 11-Jun-92 | HO67 | | LAH | 0 | 180 | 0 | 0 |
| 11-Jun-92 | HO67 | | LAH | 0 | 180 | 0 | 0 |
| 5-Jun-92 | HO67 | | LA | ** | ** | 62 | 3 |
| 5-Jun-92 | H068 | M | LA | 10 | 10 | 35.45 | 3 |
| 8-Jun-92 | H068 | | LA | 10 | 175 | 35 | 3 |
| 9-Jun-92 | H068 | | LA | 0 | 250 | 0 | 0 |
| 18-Jun-92 | H068 | | WASH | 0 | 206 | 0 | 0 |
| 1-Jun-92 | HO68 | | LA | 30 | 140 | 261 | 30 |
| 16-Jun-92 | HO68 | | LA | 33 | 221 | 51 | 12 |
| 11-Jun-92 | HO68 | | WASH | 0 | 217 | 0 | 0 |
| 1-May-92 | H084 | F | LA | 0 | 90 | 0 | 0 |
| 14-May-92 | H084 | | LA | 0 | 365 | 115 | 0 |
| 3-Jun-92 | H084 | | LA | 0 | 195 | 0 | 0 |
| 21-Apr-92 | H084 | | LAC | 0 | 190 | 0 | 0 |
| 11-Jun-92 | H084 | | LA | 0 | 225 | 39.5 | 0 |
| 19-Jun-92 | H084 | | LA | 0 | 160 | 0 | 0 |
| 13-Apr-92 | S108 | F | LA | 32 | 315 | 20 | 11 |
| 9-Jun-92 | S108 | | LA | 0 | 250 | 0 | 0 |
| 11-May-92 | S108 | | LA | 124 | 177 | 65 | 15 |
| 18-Jun-92 | S108 | | LA | 0 | 190 | 0 | 0 |
| 1-Jun-92 | S108 | | LA | 23 | 177 | 118 | 7 |

** missing data

Appendix I F. (continued)

| *Date* | *Tortoise Identification* | *Sex* | *Habitat Type* | *Time Foraging (minutes)* | *Time Total (minutes)* | *Distance Travelled (meters)* | *Number of Patches* |
|---|---|---|---|---|---|---|---|
| 3-Jun-92 | S108 | | LA | 47 | 47 | 96 | 17 |
| 23-Apr-92 | S131 | M | LA | 0 | 190 | 6 | 0 |
| 19-May-92 | S131 | | LA | 0 | 260 | 0 | 0 |
| 5-Jun-92 | S131 | | LA | 22 | 146 | 13 | 3 |
| 10-Jul-92 | S131 | | LA | 0 | 215 | 0 | 0 |
| 9-Jun-92 | s131 | | LA | 97 | 174 | 21 | 6 |
| 16-Jun-92 | S131 | | LA | 0 | 204 | 0 | 0 |
| 1-Jun-92 | S131 | | LA | 0 | 240 | 0 | 0 |
| 23-Apr-92 | S153 | F | LA | 85 | 89 | 132 | ** |
| 11-Jun-92 | S153 | | LA | 0 | 210 | 0 | 0 |
| 19-Jun-92 | S153 | | LA | 74 | 109 | 23 | 7 |
| 1-Jun-92 | S153 | | LA | 6 | 38 | 30 | 2 |
| 23-Apr-92 | S156 | M | LA | 4 | 185 | 56 | 2 |
| 19-May-92 | S156 | | LA | 37 | 278 | 306 | 14 |
| 3-Jun-92 | S156 | | LA | 51 | 179 | 45 | 6 |
| 10-Jul-92 | S156 | | LA | 0 | 204 | 0 | 0 |
| 27-May-92 | S156 | | LA | 52 | 90 | 75 | 27 |
| 9-Jun-92 | S156 | | LA | 120 | 130 | 101 | 28 |
| 11-Jun-92 | S156 | M | LA | 0 | 215 | 0 | 0 |
| 18-Jun-92 | S156 | | LA | 0 | 202 | 0 | 0 |
| 22-Jun-92 | S156 | | LA | 0 | 235 | 0 | 0 |
| 1-Jun-92 | S156 | | LA | ** | ** | 65 | 20 |
| 3-Jun-92 | unmarked | | LA | 51 | 120 | 10 | 7 |

** missing data

Appendix II. Sample desert tortoise field observation data sheets.

## Appendix II. Sample desert tortoise field observation data sheets.

### TORTOISE OBSERVATION DATA SHEET PAGE 1 / 4

INITIAL DATA:

SITE LF
DATE 27 May 1992
OBSERVER LAD
CLOUD COVER 1%
HABITAT LATR-AMDU
TORT FREQ. 148.330
NOTCH: L ____ R ____
WIND Beaufort 1 very humid!..
VEG ASSOCIATION LATR-AMDU
TORT # 315b
SLOPE ____ ASPECT ____
Tamb 24.5 Tica 25.5 Tsoil 25.5°C
ASSOC. ANNUALS SCBA (cured & green)
ERCI (cured & green); LEFR (cured; seed) CHBR (gr-cured)
ERTH (green; flower); BRRU (cured; seed); MOBE (cured; drop seed

TIME: OBSERVATIONS:

0925 Tort located out: in open in full sun. Has already been out
foraging (produced a scat). Tort saw observer approach, observer backs out of view

0943 Tort travels slowly to the north, then west, 1m pauses briefly &
continues, sniffs ground continues west 1m, pauses in shade of
AMDU, continues northwest. Pauses in full shade AMDU, rear
limbs outstretched

0950 Tort continues northwest, ① [4 SCBA (green); 8 SCBA (gr.)] continues north
west 1 m, ② [2 SCBA] sniffs ground, continues northwest 1 meter,
③ [5 SCBA, 7 ERCI (green), 6 ERCI] pauses,

0955 continues west, ④ [8 ERCI] continues northwest (same patch) moves
slowly into new patch, [10 ERCI, 10 ERCI, 5 ERCI 2 ERCI, 5 ERCI,
11 ERCI, 3, 2] continues northwest, 1 meter, ⑥ [6 SCBA] continues
northwest.

0957 Tort pauses (saw observer)

0959 continues northwest, pauses in partial shade of LATR,

1000 [4 SCBA, 25 SCBA,

1001 Tort continues, 4 SCBA (same patch), 5 SCBA] continues north
1 m, ⑥ [4 ERCI, 3 SCBA] continues northwest 1 meter, 5 ERCI,
6 ERCI, 12 ERCI, 9 SCBA, continues northwest (same patch)
1 meter, 1 meter 2 SCBA] pauses briefly & continues,
1 ~~meter~~ more meter,

1005 Paused in full sun ⑦

1006 continues northwest, [2 SCBA] 2 meters, 2 meters to the northwest

1007 Pauses briefly, continues north 1 meter, ⑧ [2 ERCI, 5] bears
east 1 meter 1 meter ⑨ [6 ERCI, 3 ERCI, 8, 2, 4, 2 continues
north, (same patch) 5 ERCI, 11, 3 (ERCI w/ flowers), 5, 11, 6]

1010 Tort pauses briefly, turns 180° (faces south)

1014 Tort turns 90° to east still eating ⑩ [ERCI 10] continues
north ½ meter, ⑪ [2 ERCI, continues northeast, then ~~south~~ east
1 meter 1 meter, 5 ERCI, into dendritic wash ⑫ 5 ERCI,
(into wash) ⑫ [8 SCBA] (on edge of wash) 1 meter (faces northwest
up dendritic wash, 3 1 meter ⑬ [4 SCBA, 11] heads out
⑮ of wash 1 meter, ⑭ [2 SCBA] 1 meter to the northwest
[10 SCBA, 11 SCBA] continues northeast ⑮ [7 SCBA, 10, 4]

Appendix II. Continued.

continues 1 meter (back into patch)⑰[5 SCBA] 1 meter bears
northeast, 2 meters, 1 meter onto hummock of sand where
LATR grows & dense monoculture of SCBA (mostly cured)
continues east, 1 meter & pauses briefly, 1 more √:
meter, continues east, ⑱[10 SCBA] 1 meter, 1 meter, 2 meters,
1025 Pauses briefly continues southeast ⑲[9 ERCI, 12 SCBA,
4 ERCI, 9 ERCI, 4, 5; (5, 4 PLPA) (green, curing), 13 ERCI]
1028 Tortoise's paused in full sun briefly, continues, 1 m
⑳[15 PLPA, 15 ERCI] continues 1 m, ㉑[28 ERCI, continues
northeast, 4 SCBA, 10 ERCI, 5, continues north-northwest
22 ERCI, 8]
1032 Tort paused in full sun/part'l shade LATR, ~~sat of~~ 1 m
1034 Cont, north-northeast, 1 meter, ㉒[10 ERCI, 5; 5 PLPA, 3 SCBA, 4, 4
3 SCBA, 14 ERCI (green), 2 SCBA, 9, 10] circles south, ㉓[7 ERCI
continues south 6 SCBA, 12 ERCI (green), 6 PLPA, 11 SCBA (green)]
continues southeast in partial shade of LATR, 1 meter into
new patch ㉔[5 ERCI (green),
1040 Paused in partial shade, 1 ERCI, 3, 2] continues southeast
1 meter, ㉕[5 ERCI, 3] continues southeast 1 m, 3 ERCI], 1 meter,
㉖[4 ERCI, 6 ERCI, 10 PLPA, 10 ERCI, 5 ERCI, circles west, 10 SCBA
3 SCBA 10 ERCI, tort pauses briefly in full sun,
1044 continues southwest ㉗[3 ERCI, 9 PLPA, sniffs KOBE but passes,
2 SCBA, 2 ERCI] circles nw, 2 meters, 1 meters bears southwest:
toward dendritic wash 3 m, into dendritic wash,
1047 Paused beneath part'l shade of AMDU
1050 continues nw up dendritic wash 2 m, @ entrance of burrow
@ edge of wash
1051 Enters burrow into full shade; digs to get into burrow &
kicking sand out of burrow.
$T_a = 30°C$ $T_g = 34°C$ $T_{1cm} = 31°C$
1055 Tort quits digging. End of observation

Appendix II. Continued.

PAGE 2 / 4

SUMMARY OF OBSERVATIONS

| SPECIES | #BITES | #PATCHES | PHENOLOGY OF PLANT SPECIES |
|---|---|---|---|
| ERCI | 410 | 16 | mostly green; some cured; some 2° flowers, some seed |
| SCBA | 240 | 19 | cured w/new green growth; seed |
| PLPA | 54 | 7 | curing→cured; seed. |
|  | 704 |  |  |

|  | O | E |
|---|---|---|
| SPECIES | USE | AVAILABILITY |
| ERCI | 16 | 23 |
| SCBA | 19 | 27 |
| PLPA | 7 | 17 |
| BRRU | 0 | 20 |
| MOBF | 0 | 13 |
| LEFL | 0 | 7 |
| CHRI | 0 | 4 |
| LASE | 0 | 1 |
| STLO | 0 | 1 |
| FEOC | 0 | 1 |
| LATE | 0 | 7 |
| AMDU | 0 | 7 |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

Appendix II. Continued.

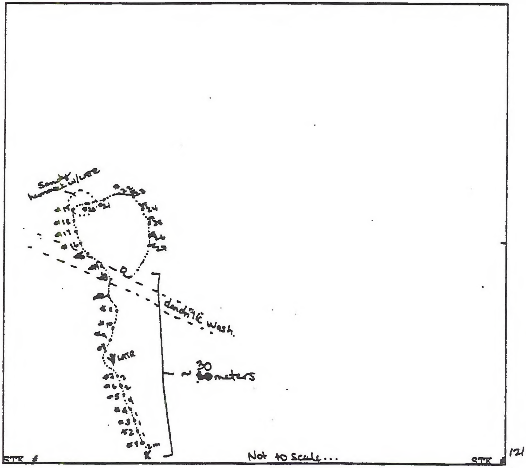
FINAL DATA: T___ 35 meters

INITIAL LOCATION: 272° FROM STAKE# 121 @ 125 meters (176 paces)
FROM STAKE#
FINAL LOCATION: 295° FROM STAKE# 121 @ 140 meters
FROM STAKE#

T___: 90 minutes
T___: 52 minutes

STK #

STK #120



STK #

Not to Scale...

STK # 121

Mark X where started and O where ended. Show tortoise's path.

Appendix III. Summary precipitation statistics and monthly precipitation totals for: the City Creek Site at St. George, Utah (A) and, the Littlefield Site, Beaver Dam, Arizona (B).

Appendix III A. Summary precipitation (mm) data for the City Creek Site:1928 - 1992.
Weather Station Location: St. George, Washington County, Utah.
Lat: 37N:06:00; Long: W113:35:00
Elevation 940 meters above mean sea level (3083 feet).

| | *Highest Total Monthly Precipitation* | *Record Year* | *Minimum Monthly Precipitation* | *Monthly Mean 1928 - 1992* | *Monthly St. Deviation* |
|---|---|---|---|---|---|
| January | 113.28 | 1980 | 0.0 | 25.91 | 21.08 |
| February | 91.69 | 1932 | 0.0 | 24.13 | 19.81 |
| March | 111.25 | 1978 | 0.0 | 24.89 | 25.15 |
| April | 72.64 | 1988 | 0.0 | 12.45 | 13.46 |
| May | 50.04 | 1977 | 0.0 | 10.16 | 12.45 |
| June | 44.45 | 1932 | 0.0 | 5.08 | 7.62 |
| July | 43.94 | 1936 | 0.0 | 14.99 | 12.19 |
| August | 58.93 | 1983 | 0.0 | 17.78 | 15.24 |
| September | 105.66 | 1939 | 0.0 | 14.48 | 17.78 |
| October | 77.98 | 1957 | 0.0 | 15.49 | 18.03 |
| November | 64.77 | 1931 | 0.0 | 17.78 | 17.02 |
| December | 72.14 | 1940 | 0.0 | 21.34 | 17.78 |
| *Monthly Precipitation Grand Total Means* | | | | 202.95 | 62.23 |

*Greatest Total Annual Rainfall was in 1941*

Appendix III A ii. Monthly precipitation (mm) totals for the City Creek Site:1987 - 1992.

| | *1987* | *1988* | *1989* | *1990* | *1991* | *1992* |
|---|---|---|---|---|---|---|
| January | 33.02 | 33.78 | 25.40 | 10.41 | 19.05 | no data |
| February | 22.61 | 7.62 | 20.07 | 31.75 | 13.72 | no data |
| March | 23.62 | 6.60 | 10.92 | 6.35 | 39.88 | no data |
| April | 7.37 | 72.64 | 0.00 | 14.22 | 1.02 | 0.00 |
| May | 18.54 | 2.29 | 12.45 | 4.06 | 3.56 | 6.60 |
| June | 5.08 | 20.07 | 0.25 | 8.38 | 5.59 | trace |
| July | 34.54 | 9.65 | 4.83 | 2.54 | 2.54 | 8.64 |
| August | 7.11 | 40.89 | 38.35 | 15.75 | 3.56 | no data |
| September | 7.62 | 4.06 | 0.00 | 20.07 | 0.71 | trace |
| October | 50.29 | 1.02 | 7.37 | 5.08 | no data | 38.10 |
| November | 31.75 | 14.73 | 0.51 | 2.79 | no data | no data |
| December | 10.41 | 24.64 | 0.00 | 5.08 | 16.26 | no data |
| *Total Annual Precipitation* | 251.97 | 238.00 | 120.14 | 126.49 | incomplete | incomplete |

Appendix III B. Summary precipitation (mm) data for the Littlefield Site:1956 - 1992.
Weather Station Location: Beaver Dam, Mohave County, Arizona.
Lat: N36:54:00; Long: W113:56:00
Elevation = 573 meters above mean sea level (1880 feet)

| | *Highest Total Monthly Precipitation* | *Record Year* | *Minimum Monthly Precipitation* | *Monthly Mean 1956 - 1992* | *Monthly St. Deviation* |
|---|---|---|---|---|---|
| January | 73.66 | 1980 | 0.0 | 22.61 | 19.81 |
| February | 74.17 | 1969 | 0.0 | 20.32 | 19.30 |
| March | 74.17 | 1978 | 0.0 | 25.91 | 24.13 |
| April | 38.10 | 1988 | 0.0 | 10.41 | 10.67 |
| May | 49.78 | 1977 | 0.0 | 10.16 | 13.97 |
| June | 28.45 | 1987 | 0.0 | 3.30 | 6.10 |
| July | 81.03 | 1984 | 0.0 | 13.46 | 16.26 |
| August | 56.90 | 1983 | 0.0 | 18.54 | 16.51 |
| September | 45.21 | 1972 | 0.0 | 11.94 | 13.46 |
| October | 54.61 | 1987 | 0.0 | 15.75 | 17.02 |
| November | 63.75 | 1967 | 0.0 | 20.07 | 16.00 |
| December | 56.39 | 1984 | 0.0 | 14.22 | 16.51 |
| *Monthly Precipitation Grand Total Means* | | | | 186.94 | 58.67 |

*Greatest Total Annual Rainfall was in 1978*

Appendix III B ii. Monthly and (mm) totals for the Littlefield Site:1987 - 1992.

| | *1987* | *1988* | *1989* | *1990* | *1991* | *1992* |
|---|---|---|---|---|---|---|
| January | 25.65 | 39.88 | 39.62 | 18.03 | 15.75 | 24.64 |
| February | 25.91 | 5.33 | 15.24 | 60.71 | 7.11 | 38.10 |
| March | 27.18 | 1.52 | 14.99 | 3.30 | 47.24 | 82.04 |
| April | 6.35 | 38.10 | 0.00 | 11.18 | trace | 0.00 |
| May | 5.33 | 6.10 | 13.97 | 10.41 | 9.91 | 27.94 |
| June | 28.45 | 8.64 | 0.51 | 8.38 | 2.79 | 0.76 |
| July | 16.51 | 13.46 | 25.40 | 22.35 | 44.45 | 3.05 |
| August | 20.07 | 30.48 | 44.20 | 21.59 | 3.05 | 7.37 |
| September | 2.79 | 2.79 | 3.05 | 34.29 | 6.86 | 1.27 |
| October | 54.61 | 0.76 | 26.42 | 7.11 | 17.27 | 36.32 |
| November | 30.48 | 8.89 | 0.00 | 24.38 | 10.16 | no data |
| December | 10.16 | 21.34 | 0.00 | 2.54 | 17.53 | no data |
| Total Annual Precipitation | 253.49 | 177.29 | 183.39 | 224.28 | 182.12 | incomplete |

Appendix IV. Flora of the City Creek Site (A) and, the Littlefield Site (B) organized by growth form.

## Appendix IV A. Flora of the City Creek Site, 1989-1993.

| GROWTH FORM / SPECIES | CODE | COMMON NAME | YR. | FAMILY |
|---|---|---|---|---|
| **Tree** | | | | |
| *Celtis reticulata* | CERI | netleaf hackberry | all | Ulmaceae |
| *Chilopsis linearis* | CHLI | desert willow | all | Bignoniaceae |
| *Fraxinus anomala* | FRAN | singleleaf ash | all | Oleaceae |
| *Juniperus osteosperma* | JUOS | Utah juniper | all | Cupressaceae |
| *Prosopis pubescens* | PRPU | screwbean mesquite | all | Leguminosae |
| *Prosopis juliflora* | PRJU | honey mesquite | all | Leguminosae |
| **Perennial Shrub** | | | | |
| *Acamptopappus sphaerocephalus* | Acamp | golden head | 89 | Compositae |
| *Ambrosia dumosa* | AMDU | bursage | all | Compositae |
| *Arenaria macradenia* | ARMA | shrubby sandwort | 90-91 | Caryophyllaceae |
| *Artemesia filifolia* | ARFI | sand sagebrush; old-man sage | all | Compositae |
| *Atriplex canescens* | ATCA | four-wing saltbrush | all | Chenopodiaceae |
| *Baccharis sp.* | Bacc. | desert broom | all | Compositae |
| *Brickelia sp.* | Brick. | bricklebush | all | Compositae |
| *Ceratoides lanata* | CELA | winterfat; white-sage | all | Chenopodiaceae |
| *Chrysothamnus sp.* | | rabbit brush | all | Compositae |
| *Coleogyne ramosissima* | CORA | blackbrush | all | Rosaceae |
| *Cowania mexicana* | COME | cliff-rose | all | Rosaceae |
| *Encelia frutescens* | ENFR | bush encelia | all | Compositae |
| *Ephedra nevadensis* | EPNE | Nevada ephedra | all | Ephedraceae |
| *Ephedra viridis* | EPVI | green ephedra; Mormon tea | all | Ephedraceae |
| *Eriogonum fasciculatum* | ERFA | Mojave buckwheat | all | Polygonaceae |
| *Fallugia paradoxa* | FAPA | Apache plume | all | Rosaceae |
| *Gutierrezia microcephala* | GUMI | thread snakeweed | all | Compositae |
| *Gutierrezia sarothrae* | GUSA | broom snakeweed | all | Compositae |
| *Hymenoclea salsola* | HYSA | burrobush | all | Compositae |
| *Hymenopappus filifolius* | HYFI | hyaline herb | all | Compositae |
| *Krameria parvifolia* | KRPA | range ratany | all | Krameriaceae |
| *Larrea tridentata* | LATR | creosote bush | all | Zygophyllaceae |
| *Lepidium fremontii* | LEFR | desert allysum | 90-91 | Cruciferae |
| *Lotus rigidus* | LORI | bush trefoil | all | Leguminosae |
| *Lycium sp.* | | wolfberry | all | Solanaceae |
| *Prunus fasciculata* | PRFA | desert peach; desert almond | all | Rosaceae |
| *Rhus trilobata* | RHTR | skunkbush | all | Anacardiaceae |
| *Salazaria mexicana* | SAME | bladdersage; paperbag bush | all | Labiatae |
| *Sphaeralcea ambigua* | SPAM | desert mallow | 90-91 | Malvaceae |
| *Stephenomeria paucifolia* | STPA | fewflower wire lettuce | all | Compositae |
| *Tamarix pentandra* | TAPE | tamarisk; Saltcedar | all | Tamaricaceae |
| *Tetradymia spinosa* | TESP | thorny horsebush | all | Compositae |
| **Perennial Forb** | | | | |
| *Abronia fragrans* | ABFR | fragrant sand verbena | all | Nyctaginaceae |
| *Allionia incarnata* | ALIN | windmills | 90-91 | Nyctaginaceae |
| *Androstephium breviflorum* | ANBR | [hyacinth] | 90-91 | Liliaceae |
| *Anemone tuberosa* | ANTU | desert anemone | 90-91 | Ranunculaceae |
| *Arabis drummondii* | ARDR | rockcress | 90-91 | Cruciferae |
| *Aster mohavensis* | Aster sp. | Mojave Aster | all | Compositae |
| *Baileya multiradiata* | BAMU | desert marigold | 90-91 | Compositae |
| *Baileya pleniradiata* | BAPL | woolly marigold | 90-91 | Compositae |
| *Calochortus nuttallii* | CANU | sego lily | all | Liliaceae |
| *Camissonia brevipes* | CABR | yellow cups | 89 | Onograceae |
| *Carex geyeri* | CAGE | elk sedge | all | Cyperaceae |
| *Castilleja linariaefolia* | CALI | narrowleaf paintbrush | all | Scrophulariaceae |
| *Croton californicus* | CRCA | Mohave croton | all | Euphorbiaceae |
| *Datura metaloides* | DAME | sacred datura | all | Solanaceae |
| *Delphinium nuttallianum* | DENU | Nelson larkspur | all | Ranunculaceae |
| *Dichelostemma pulchellum* | DIPU | blue dick | 90-91 | Liliaceae |
| *Erigeron divergens* | ERDI | spreading daisy | all | Compositae |

Appendix IV A. (Continued)

| GROWTH FORM /SPECIES | CODE | COMMON NAME | | FAMILY |
|---|---|---|---|---|
| **Perennial Forb** | | | | |
| *Eriogonum inflatum* | ERIN | bottlebush; desert trumpet | all | Polygonaceae |
| *Gaura coccinia* | GACO | scarlet gaura | all | Onagraceae |
| *Heterotheca villosa* | HEVI | hairy goldenaster | all | Compositae |
| *Lomatium scabrum* | LOSC | rough lomatium; cliff lomatium | 90-91 | Apiaceae |
| *Nicotiana trigonophylla* | NITR | desert tobacco | all | Nyctaginaceae |
| *Mirabilis multiflora* | MIMU | desert four-o'clock | all | Nyctaginaceae |
| *Oenothera pallida* | OEPA | pale evening-primrose | all | Onagraceae |
| *Pediomelum mephiticum* | PEME | skunk breadroot | 90 | Leguminosae |
| *Penstemon ambiguus* | PEAM | bush penstemon; gilia penstemon | all | Scrophulariaceae |
| *Penstemon eatoni* | PEEA | Eaton penstemon; scarlet-bugler | all | Scrophulariaceae |
| *Rumex hymenosepalus* | RUHY | canaigre | all | Polygonaceae |
| *Senecio douglasii* | SEDO | Douglas Groundsel | all | Compositae |
| *Stephanomeria exigua* | STEX | wire lettuce | 90-91 | Compositae |
| **Cactus** | | | | |
| *Echinocereus engelmannii* | ECEN | Engelmann hedgehog cactus | all | Cactaceae |
| *Mammillaria tetrancistra* | MATE | corkseed cactus | all | Cactaceae |
| *Opuntia acanthocarpa* | OPAC | buckhorn cholla | all | Cactaceae |
| *Opuntia erinacea* | OPER | prickley pear | all | Cactaceae |
| **Yucca** | | | | |
| *Yucca baccata* | YUBA | datil yucca; fleshy-fruited yucca | all | Agavaceae |
| *Yucca utahensis* | YUUT | Utah yucca | all | Agavaceae |
| **Ferns and Fern Allies** | | | | |
| *Notholaena sp.* | Nothol. | cloak-fern | all | Polypodiacae |
| *Selaginella watsonii* | SEWA | Watson Spikemoss | all | Selaginellaceae |
| **Perennial grass** | | | | |
| *Aristida purpurea* | ARPU | purple threeawn | all | Graminae |
| *Elymus elymoides** | ELEL | squirrel tail | all | Graminae |
| *Erioneuron pulchellum* | ERPU | fluffgrass | all | Graminae |
| *Hilaria rigida* | HIRI | big galleta | all | Graminae |
| *Muhlenbergia porteri* | MUPO | bush muhly | all | Graminae |
| *Sporobolus flexuosus* | SPFL | mesa dropseed | all | Graminae |
| *Stipa hymenoides*** | STHY | indian ricegrass | all | Graminae |
| *Stipa speciosa* | STSP | desert needlegrass | all | Graminae |
| *Stipa (comata or neomexicana)* | STCO | needlegrass | all | Graminae |
| *Tridens muticus* | TRMU | slim tridens | all | Graminae |
| **Winter Annual Forb** | | | | |
| *Amsinkia tessellata* | AMTE | rough fiddleneck | 90-91 | Boraginaceae |
| *Astragalus nuttalli* | ASNU | Nuttall locoweed | all | Leguminosae |
| *Avena fatua* | AVFA | oats | 92 | Graminae |
| *Camissonia andina* | CAAN | | 90-91 | Onagraceae |
| *Camissonia Boothii* | CADE | bottlebrush | 92 | Onagraceae |
| *Chenopodium album* | CEAL | lambsquarter; pigweed | 90-91 | Chenopodiaceae |
| *Chorizanthe brevicornu* | CHBR | short spine-flower | 90-91 | Polygonaceae |
| *Chorizanthe rigida* | CHRI | rigid spine-flower | 90-91 | Polygonaceae |
| *Chorizanthe thurberi* | CHTH | Thurber spine-flower | all | Polygonaceae |
| *Corydalis aurea* | COAU | golden corydalis | all | Fumariaceae |
| *Cryptantha angustifolia* | CRAN | narrowleaf cryptanth | 90-91 | Boraginaceae |
| *Cryptantha micrantha* | CRMI | dye cryptanth | all | Boraginaceae |
| *Cryptantha nevadensis* | CRNE | Nevada cryptanth | 90-91 | Boraginaceae |
| *Cryptantha virginensis* | CRVI | Virgin cryptanth | 90-91 | Boraginaceae |
| *Descurainia pinnata* | DEPI | pinnate tansy-mustard | 90-91 | Cruciferae |
| *Dithyrea wislizenii* | DIWI | spectacle-pod | all | Cruciferae |

* formerly *Sitanian hystrix*
** formerly *Orozopsis hymenoides*

Appendix IV A. (Continued)

| GROWTH FORM /SPECIES | CODE | COMMON NAME | | FAMILY |
|---|---|---|---|---|
| **Winter Annual Forb** | | | | |
| *Draba cuneifolia* | DRCU | wedgeleaf | 90-91 | Cruciferae |
| *Eriastrum diffusum* | ERDIF | | 92 | Polemoniaceae |
| *Eriastrum eremicum* | ERER | desert gilia | all | Polemoniaceae |
| *Eriogonum maculatum* | ERMA | red-spotted buckwheat | all | Polygonaceae |
| *Eriogonum thomasii* | ERTH | Thomas buckwheat | all | Polygonaceae |
| *Eriogonum nidularum* | ERNI | bird nest buckwheat | all | Polygonaceae |
| *Eriophyllum wallacei* | ERWA | Wallace woollyleaf; woolly daisy | all | Compositae |
| *Erodium cicutarium* | ERCI | storksbill, filaree | all | Geraniaceae |
| *Eschscholtzia minutiflora* | ESMI | little gold-poppy | 90-91 | Papaveraceae |
| *Euphorbia parryi* | EUPA | Parry spurge | all | Euphorbiaceae |
| *Euphorbia micromera* | EUMI | sand mat | 92 | Euphorbiaceae |
| *Gilia leptomeria* | GILE | tooth-leaved gilia | 90-91-92 | Polemoniaceae |
| *Gilia scopulorum* | GISC | rock gilia | 92 | Polemoniaceae |
| *Helianthus anomalus* | HEAN | sand sunflower | all | Compositae |
| *Langloisia setosissima* * | LASE | bristly gilia | all | Polemoniaceae |
| *Lepidium flavum* | LEFL | yellow pepper-grass | 90-91 | Cruciferae |
| *Lesquerella tenella* | LETE | slender bladderpod | 90-91 | Cruciferae |
| *Linanthus dichotomous* | LIDI | | | Polemoniaceae |
| *Lotus plebeius* | LOPL | three-bracted trefoil | all | Leguminosae |
| *Lupinus concinnus* | LUCO | elegant lupine | all | Leguminosae |
| *Mentzelia albicaulis* | MEAL | small-flowered blazing star | all | Loasaceae |
| *Microseris lindleyi* | MILI | silver-puffs | 90-91 | Compositae |
| *Monoptilon bellioides* | MOBE | Mojave desert star | 92 | Compositae |
| *Oenothera brevipes* | OEBR | yellow cups | 90-91 | Onagraceae |
| *Oenothera deltoides* | OEDE | annual evening primrose | 92 | Onagraceae |
| *Oenothera primivera* | OEPR | evening primrose | 92 | Onagraceae |
| *Palafoxia arida* | PAAR | Spanish needle | all | Compositae |
| *Pectocarya recurvata* | PERE | bent combseed | all | Boraginaceae |
| *Pectocarya setosa* | PESE | saucer combseed | 90-91 | Boraginaceae |
| *Phacelia ambigua* | PHAM | notch-leaf phacelia | 90-91 | Hydrophyllaceae |
| *Phacelia bicolor* | PHBI | two-colored Phacelia | 92 | Hydrophyllaceae |
| *Phacelia crenulata* | PHCR | notch-leaved Phacelia | 92 | Hydrophyllaceae |
| *Phacelia ivesiana* | PHIV | Ives phacelia | 90-91 | Hydrophyllaceae |
| *Phacelia tanacetifolia* | PHTA | lacy phacelia | 90-91 | Hydrophyllaceae |
| *Plagiobothrys arizonicus* | PLAR | stainplant | 90-91 | Boraginaceae |
| *Plantago patagonica* | PLPA | plantain | all | Plantaginaceae |
| *Plantago insularis* | PLIN | woolly plantain | 90-91 | Plantaginaceae |
| *Salsola iberica* | SAIB | Russian-thistle; tumbleweed | all | Chenopodiaceae |
| *Silene antirrhina* | SIAN | catch-fly | all | Caryophyllaceae |
| *Stephanomeria exigua* | STEX | annual Wirelettuce | all | Compositae |
| *Streptanthella longirostris* | STLO | long-beaked twist-flower | 90-91 | Compositae |
| *Stylocline micropoides* | STMI | desert nest-straw | 92 | Compositae |
| *Thysanocarpus curvipes* | THCU | fringe-pod | 90-91 | Cruciferae |
| **Winter Annual Grass** | | | | |
| *Bromus diandrus* | BRDI | rip gut brome | 92 | Graminae |
| *Bromus rubens* | BRRU | red brome; foxtail brome | all | Graminae |
| *Bromus tectorum* | BRTE | cheatgrass; downy chess | all | Graminae |
| *Festuca octoflora* | FEOC | six weeks fescue | 92 | Graminae |
| *Schismus barbatus* | SCBA | Mediterranean grass | all | Graminae |
| **Summer Annual Forb** | | | | |
| *Pectis papposa* | PEPA | chinch-weed | 90-91 | Compositae |
| **Summer Annual Grass** | | | | |
| *Bouteloua aristidoides* | BOAR | needle grama | 90-91 | Graminae |

* formerly *Langloisia schottii*

Appendix IV B. Complete flora of the Littlefield Study Site, 1990-1993.

| GROWTH FORM / SPECIES | CODE | COMMON NAME | YR. | FAMILY |
|---|---|---|---|---|
| **Perennial Shrub** | | | | |
| *Ambrosia dumosa* | AMDU | bur-sage | all | Compositae |
| *Atriplex canescens* | ATCA | four-wing saltbrush | all | Chenopodiaceae |
| *Baccharis sp.* | Bacc. | baccharis | all | Compositae |
| *Ceratoides lanata* | CELA | winterfat; white-sage | all | Chenopodiaceae |
| *Ephedra nevadensis* | EPNE | Nevada ephedra | all | Ephedraceae |
| *Hymenoclea salsola* | HYSA | burrobush | all | Compositae |
| *Krameria greyi* | KRGR | white ratany | all | Krameriaceae |
| *Krameria parvifolia* | KRPA | range ratany | all | Krameriaceae |
| *Larrea tridentata* | LATR | creosote bush | all | Zygophyllaceae |
| *Lycium andersonii* | LYAN | Anderson wolfberry | all | Solanaceae |
| *Lycium sp.* | Lyc. | | all | Solanaceae |
| *Sphaeralcea ambigua* | SPAM | desert mallow | all | Malvaceae |
| *Tetradymia spinosa* | TESP | thorny horsebush | all | Compositae |
| *Tiquilia canescens* | TICA | hairy tiquilia | all | Boraginaceae |
| **Perennial Forb** | | | | |
| *Androstephium breviflorum* | ANBR | hyacinth | all | Liliaceae |
| *Cynanchum utahense* | CYUT | swallow-wort | all | Astragulaceae |
| *Datura meteloides* | DAME | sacred datura | all | Solanaceae |
| *Dyssodia pentachaeta* | DYPE | scale glandweed | all | Compositae |
| *Eriogonum inflatum* | ERIN | bottlebush; desert trumpet | all | Polygonaceae |
| *Senecio douglasii* | SEDO | Douglas groundsel | all | Compositae |
| *Stephenomeria sp.* | STPA | fewflower wireletucce | all | Compositae |
| *Psoralea castorea* | Psor. | Beaver Dam breadroot | all | Leguminasae |
| **Cactus** | | | | |
| *Echinocereus engelmani* | ECEN | Engelmann hedgehog-cactus | all | Cactaceae |
| *Ferocactus acanthodes* | FEAC | barrel cactus | all | Cactaceae |
| *Mammillaria tetrancistra* | MATE | Pincushion cactus | all | Cactaceae |
| *Opuntia basilaris* | OPBA | beavertail cactus | all | Cactaceae |
| *Opuntia erinacea* | OPER | prickley pear | all | Cactaceae |
| **Perennial Grass** | | | | |
| *Aristida purpurea* | ARPU | purple threeawn | all | Graminae |
| *Erioneuron pulchellum* | ERPU | fluffgrass | all | Graminae |
| *Hilaria rigida* | HIRI | big galleta | all | Graminae |
| *Muhlenbergia porteri* | MUPO | bush muhly | all | Graminae |
| *Oryzopsis hymenoides* | ORHY | indian ricegrass | all | Graminae |
| *Tridens muticus* | TRMU | slim tridens | all | Graminae |
| **Winter Annual Forb** | | | | |
| *Atrichoseris platyphylla* | ATPL | parachute plant | 93 | Compositae |
| *Baileya pleniradiata* | BAPL | woolly marigold | all | Compositae |
| *Baileya multiradiata* | BAMU | desert marigold | all | Compositae |
| *Chaenactis fremontii* | CHFR | Fremont dusty-maiden | all | Compositae |
| *Chorizanthe brevicornu* | CHBR | short spine-flower | all | Polygonaceae |
| *Chorizanthe rigida* | CHRI | rigid spine-flower | all | Polygonaceae |
| *Descurainia pinnata* | DEPI | pinnate tansy-mustard | all | Cruciferae |
| *Eriastrum eremicum* | ERER | desert gilia | all | Polemoniaceae |
| *Eriogonum deflexum* | ERDE | skeleton weed buckwheat | 92 | Polygonaceae |
| *Eriogonum thomasii* | ERTH | Thomas buckwheat | all | Polygonaceae |
| *Erodium cicutarium* | ERCI | storksbill; red filaree | all | Geraniaceae |
| *Eschscholtzia minutifolia* | ESMI | little gold poppy | all | Papaveraceae |
| *Euphorbia micromera* | EUMI | | all | Euphorbiaceae |
| *Gilia polycladon* | GIPO | spreading gilia | 91-92 | Polemoniaceae |
| *Gilia scopulorum* | GISC | rock gilia | all | Polemoniaceae |
| *Glyptopleura setulosa* | GISE | Keysia | 92 | Compositae |
| *Hordeum murinum* | HOMU | rabbit barley | 92 | Graminae |

Appendix IVB. (Continued)

| GROWTH FORM / SPECIES | CODE | COMMON NAME | YR. | FAMILY |
|---|---|---|---|---|
| **Winter Annual Forb** | | | | |
| *Langloisia setosissima* * | LASC | | all | Polemoniaceae |
| *Lepidium flavum* | LEFL | yellow pepper-grass | all | Cruciferae |
| *Lesquerella tenella* | LETE | slender bladderpod | all | Cruciferae |
| *Linanthus dichotomus* | LIDI | | | Polemoniaceae |
| *Lotus plebieus* | LOPL | long-bracted trefoil | all | Leguminoseae |
| *Monoptilon bellioides* | MOBE | Mohave desert star | all | Compositae |
| *Oenothera brevipes* | OEBR | yellow cups | all | Onagraceae |
| *Pectocarya recurvata* | PERE | bent combseed | all | Boraginaceae |
| *Plantago insularis* | PLIN | woolly plantain | all | Plantaginaceae |
| *Plantago patagonica* | PLPA | plantain | all | Plantaginaceae |
| *Rafinesquia neomexicana* | RANE | desert chicory | all | Compositae |
| *Sisymbrium irio* | SIIR | | 92 | Cruciferae |
| **Winter Annual Grass** | | | | |
| *Bromus rubens* | BRRU | red brome; foxtail brome | all | Graminae |
| *Bromus tectorum* | BRTE | cheatgrass; downy chess | all | Graminae |
| *Schismus barbatus* | SCBA | Mediterranean grass | all | Graminae |
| **Summer Annual Forb** | | | | |
| *Pectis papposa* | PEPA | chinch-weed | all | Compositae |

* *formerly L. schottii*

Appendix V. Spring aboveground mean biomass estimates (grams/$m^2$) arranged by species for two sites in 1989 - 1992. The City Creek Site (A) and the Littlefield Site (B).

Appendix VA. Spring aboveground biomass estimates (grams/m2) by species, averaged, for the entire plot at the City Creek Site. 1989 - 1992. Values were weighted* and corrected**.

| | 1989 | | 1990 | | 1991 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| *Amsinckia tesselata* | NA | NA | NA | NA | 0.008 | 0.097 | 0.009 | 0.086 |
| *Astragalus nuttalii* | NA | NA | NA | NA | <0.001 | 0.004 | NA | NA |
| *Bromus rubens* | 0.388 | 0.823 | 0.240 | 0.929 | 0.304 | 1.059 | 2.122 | 4.541 |
| *Bromus tectorum* | 0.112 | 0.352 | 0.021 | 0.179 | 0.417 | 3.002 | 1.930 | 4.291 |
| *Bromus spp.**** | NA | NA | NA | NA | NA | NA | 4.044 | 7.100 |
| *Camissonia andina* | NA | NA | NA | NA | <0.001 | 0.002 | NA | NA |
| *Chorizanthe brevicornu* | NA | NA | NA | NA | 0.020 | 0.122 | 0.047 | 0.298 |
| *Chorizanthe thurberi* | NA | NA | NA | NA | 0.007 | 0.052 | 0.012 | 0.066 |
| *Corydalis aurea* | NA | NA | NA | NA | NA | NA | <0.001 | 0.003 |
| *Cryptantha angustifolia* | NA | NA | 0.003 | 0.023 | 0.009 | 0.077 | 0.007 | 0.054 |
| *Cryptantha micrantha* | 0.008 | 0.056 | 0.003 | 0.012 | 0.018 | 0.088 | 0.112 | 0.383 |
| *Cryptantha nevadensis* | NA | NA | <.001 | 0.002 | 0.147 | 0.832 | 0.040 | 0.254 |
| *Cryptantha virginensis* | NA | NA | 0.002 | 0.013 | NA | NA | 0.584 | 1.726 |
| *Cryptantha sp.* | NA | NA | <.001 | 0.001 | NA | NA | 0.044 | 0.251 |
| *Cryptantha spp.**** | NA | NA | NA | NA | NA | NA | 0.675 | 1.737 |
| *Descurainia pinnata* | NA | NA | 0.001 | 0.005 | 0.988 | 3.757 | 1.166 | 2.875 |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.). Areas of subhabitats (ha): Dune = 67.3, Blackbrush = 48.3, Rocky = 140.7, Trans. = 15.3, Total Area = 271.6.

** In 1989 10 quads In Trans. were eliminated randomly to standardize the # of samples per subhab.
In 1990, 10 quadrats were eliminated at random to standardize the sampling. As a result, total N of quadrats was 80.
In 1991 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 167.
In 1992 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 150.

*** *Bromus spp. - B. rubens and B. tectorum*
*Cryptantha spp. - C. angustifolia, C. nevadensis, C. virginensis*
*Gilia spp. - G. humilis, G. leptomeria*

Appendix VA. Continued

| | 1989 | | 1990 | | 1991 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| *Dithyrea wislizinii* | NA | NA | NA | NA | 0.035 | 0.414 | NA | NA |
| *Draba cuneifolia* | NA | NA | NA | NA | 0.011 | 0.050 | 0.010 | 0.039 |
| *Eriastrum diffusum* | NA | NA | 0.001 | 0.008 | 0.014 | 0.044 | 0.005 | 0.025 |
| *Eriastrum eremicum* | NA | NA | NA | NA | NA | NA | 0.016 | 0.038 |
| *Eriophyllum wallacei* | 0.002 | 0.011 | 0.005 | 0.013 | 0.045 | 0.158 | 0.107 | 0.274 |
| *Eriogonum maculatum* | NA | NA | NA | NA | NA | NA | 0.006 | 0.038 |
| *Eriogonum nidularium* | NA | NA | NA | NA | NA | NA | 0.003 | 0.023 |
| *Eriogonum thomassii* | NA | NA | NA | NA | 0.017 | 0.216 | <0.001 | 0.010 |
| *Erodium cicutarium* | 0.070 | 0.407 | 0.125 | 0.627 | 0.255 | 0.926 | 1.614 | 2.947 |
| *Euphorbia parryi* | 0.002 | 0.024 | 0.002 | 0.009 | <0.001 | 0.002 | <0.001 | 0.002 |
| *Festuca octaflora* | NA | NA | NA | NA | NA | NA | 0.310 | 0.459 |
| *Gilia humilus* | NA | NA | NA | NA | NA | NA | 0.063 | 0.212 |
| *Gilia leptomeria* | NA | NA | NA | NA | 0.019 | 0.085 | 0.014 | 0.052 |
| *Gilia sp.* | NA | NA | 0.001 | 0.007 | NA | NA | NA | NA |
| *Gilia spp.* *** | NA | NA | NA | NA | NA | NA | 0.077 | 0.216 |
| *Hymenopappus filifolius* | NA | NA | NA | NA | 0.004 | 0.047 | NA | NA |
| *Langloisia setosissima* | <0.001 | 0.003 | NA | NA | NA | NA | 0.002 | 0.021 |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.). Areas of subhabitats (ha): Dune = 67.3, Blackbrush = 48.3, Rocky = 140.7, Trans. = 15.3, Total Area = 271.6.

** In 1989 10 quads in Trans. were eliminated randomly to standardize the # of samples per subhab.
In 1990, 10 quadrats were eliminated at random to standardize the sampling. As a result, total N of quadrats was 80.
In 1991 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 167.
In 1992 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 150.

*** *Bromus spp. - B. rubens and B. tectorum*
*Cryptantha spp. - C. angustifolia, C. nevadensis, C. virginensis*
*Gilia spp. - G. humilis, G. leptomeria*

Appendix VA. Continued

| | 1989 | | 1990 | | 1991 | | 1992 | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| *Lepidium flavum* | NA | NA | <.001 | 0.002 | 0.004 | 0.050 | 0.049 | 0.355 |
| *Linanthus sp.* | <0.001 | <0.001 | NA | NA | <0.001 | 0.005 | 0.005 | 0.021 |
| *Lotus plebieus* | NA | NA | 0.002 | 0.016 | NA | NA | 0.002 | 0.011 |
| *Mentzelia albicaulus* | <0.001 | 0.004 | NA | NA | 0.004 | 0.052 | | |
| *Microcerus lindleyi* | NA | NA | 0.002 | 0.016 | 0.006 | 0.037 | 0.035 | 0.170 |
| *Pectorya recurvata* | NA | NA | <.001 | 0.001 | 0.048 | 0.140 | 0.106 | 0.376 |
| *Pectocarya setosissima* | NA | NA | NA | NA | NA | NA | 0.002 | 0.012 |
| *Phacelia bicolor* | NA | NA | NA | NA | 0.002 | 0.017 | <0.001 | 0.002 |
| *Phacelia ivesiana* | NA | NA | 0.002 | 0.008 | 0.075 | 0.370 | NA | NA |
| *Plantago insularus* | <0.001 | 0.001 | NA | NA | 0.165 | 0.722 | 0.117 | 0.488 |
| *Plantago patagonica* | NA | NA | 0.006 | 0.051 | <0.001 | 0.001 | NA | NA |
| *Salsola iberica* | NA | NA | NA | NA | 0.011 | 0.141 | NA | NA |
| *Schismus barbatus* | 0.001 | 0.006 | 0.018 | 0.084 | 0.107 | 0.365 | 0.321 | 0.810 |
| *Silene antirhinna* | NA | NA | 0.001 | 0.005 | NA | NA | 0.233 | 1.041 |
| *Stephanomeria exigua* | NA | NA | 0.001 | 0.010 | 0.003 | 0.033 | 0.126 | 0.664 |
| *Streptanthella longirostris* | NA | NA | NA | NA | 0.764 | 3.551 | 5.782 | 13.568 |
| *Stylocline micropoides* | NA | NA | NA | NA | 0.002 | 0.012 | 0.001 | 0.007 |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.). Areas of subhabitats (ha): Dune = 67.3, Blackbrush = 48.3, Rocky = 140.7, Trans. = 15.3, Total Area = 271.6.

** In 1989 10 quads in Trans. were eliminated randomly to standardize the # of samples per subhab.
In 1990, 10 quadrats were eliminated at random to standardize the sampling. As a result, total N of quadrats was 80.
In 1991 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 167.
In 1992 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 150.

*** *Bromus spp. - B. rubens and B. tectorum*
*Cryptantha spp. - C. angustifolia, C. nevadensis, C. virginensis*
*Gilia spp. - G. humilis, G. leptomeria*

Appendix VA. Continued

| Species | 1989<br>Mean | <br>Standard Deviation | 1990<br>Mean | <br>Standard Deviation | 1991<br>Mean | <br>Standard Deviation | 1992<br>Mean | <br>Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| *Thysanocarpus cuneifolia* | NA | NA | 0.001 | 0.009 | NA | NA | NA | NA |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.). Areas of subhabitats (ha): Dune = 67.3, Blackbrush = 48.3, Rocky = 140.7, Trans. = 15.3, Total Area = 271.6.

** In 1989 10 quads in Trans. were eliminated randomly to standardize the # of samples per subhab.
In 1990, 10 quadrats were eliminated at random to standardize the sampling. As a result, total N of quadrats was 80.
In 1991 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 167.
In 1992 values for Rocky subhabitat were duplicated to standardize sampling. As a result, total N of quadrats was 150.

*** *Bromus spp. - B. rubens and B. tectorum*
*Cryptantha spp. - C. angustifolia, C. nevadensis, C. virginensis*
*Gilia spp. - G. humilis, G. leptomeria*

Appendix VB. Spring aboveground biomass estimates(grams/ m2) by species, averaged, for the entire plot at the Littlefield Site. 1990 - 1992. Data were weighted* and corrected**. Cells for which no data were available were denoted by "NA".

| | **1990** | | **1991** | | **1992** | |
|---|---|---|---|---|---|---|
| **SPECIES** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| *Astragalus nuttaliannus* | | | 0.037 | 0.324 | 0.032 | 0.188 |
| *Bromus rubens* | 0.642 | 1.488 | 0.772 | 2.183 | 11.031 | 26.259 |
| *Bromus tectorum* | 0.004 | 0.032 | 0.025 | 0.181 | 0.264 | 0.907 |
| *Bromus spp.**** | NA | NA | NA | NA | 11.290 | 26.300 |
| *Chorizanthe brevicornu* | 0.010 | 0.082 | <0.001 | <0.001 | 0.027 | 0.242 |
| *Chorizanthe rigida* | NA | NA | 0.014 | 0.095 | 0.012 | 0.070 |
| *Descurainia pinnata* | 0.001 | 0.004 | 0.017 | 0.208 | <0.001 | <0.001 |
| *Draba cuneifolia* | NA | NA | 0.018 | 0.221 | <0.001 | 0.005 |
| *Eriastrum eremicum* | 0.006 | 0.026 | 0.050 | 0.268 | 0.003 | 0.027 |
| *Eriastrum diffusum* | NA | NA | NA | NA | 0.002 | 0.015 |
| *Eriogonum thomassii* | 0.172 | 0.472 | 2.078 | 5.453 | 2.636 | 7.830 |
| *Erodium cicutarium* | 0.747 | 2.271 | 1.061 | 3.205 | 2.533 | 5.845 |
| *Erodium texanum* | NA | NA | 0.113 | 0.978 | 0.042 | 0.222 |
| *Euphorbia parryi* | <0.001 | <0.001 | NA | NA | NA | NA |
| *Festuca octaflora* | NA | NA | NA | NA | 0.192 | 0.604 |
| *Gilia humilus* | NA | NA | NA | NA | <0.001 | <0.001 |
| *Gilia polycladon* | NA | NA | NA | NA | 0.003 | 0.015 |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.)
Area (ha) of each subhabitat is: Total - 273.5; LAH-70.7; LA - 155.4; LAC - 24.6; and Wash - 0.23.

** In 1990, LAC quadrats were duplicated, and 14 LAH-quadrats were duplicated at random to standardize sampling.
Resulting in 134 total quadrats.
In 1991, each wash quadrat was multiplied by 10 to correct for the area of the original quadrats relative to other sampling.
In 1992, some quadrats were duplicated to standardize sampling: LA = 16; LAC = 8; and Wash = 6.
Resulting in 177 total quadrats.

*** *Bromus spp. - B. rubens and B. tectorum*

Appendix V B. (Continued).

| | **1990** | | **1991** | | **1992** | |
|---|---|---|---|---|---|---|
| **SPECIES** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| *Gilia scopulorum* | NA | NA | NA | NA | 0.006 | 0.037 |
| *Hordeum* | NA | NA | NA | NA | <0.001 | <0.001 |
| *Langloisia setosissima* | NA | NA | 0.001 | 0.011 | 0.004 | 0.021 |
| *Lepidium flavum* | 0.006 | 0.039 | 0.203 | 0.832 | 1.624 | 5.403 |
| *Lesquerella tenella* | 0.007 | 0.048 | 0.194 | 0.910 | 0.419 | 2.425 |
| *Linanthus diffusum* | NA | NA | NA | NA | <0.001 | <0.001 |
| *Lotus plebieus* | <0.001 | 0.003 | NA | NA | NA | NA |
| *Monoptilon bellioides* | 0.005 | 0.022 | 0.041 | 0.210 | 0.168 | 0.437 |
| *Oenothera primiverus* | NA | NA | 0.003 | 0.031 | NA | NA |
| *Pectocarya recurvata* | <0.001 | 0.001 | 0.004 | 0.026 | 0.105 | 0.558 |
| *Phacelia ivesiana* | NA | NA | 0.006 | 0.048 | NA | NA |
| *Plantago insularis* | NA | NA | 0.279 | 0.896 | 0.093 | 0.333 |
| *Plantago patagonica* | 0.200 | 0.311 | 0.610 | 1.463 | 0.886 | 1.931 |
| *Rafinesquia neomexicanus* | NA | NA | NA | NA | 0.090 | 0.671 |
| *Schismus barbatus* | 1.049 | 1.911 | 2.052 | 4.302 | 25.718 | 49.292 |
| *Stephanomeria exigua* | NA | NA | NA | NA | 0.006 | 0.078 |
| *Streptanthella longirostris* | NA | NA | NA | NA | 0.093 | 0.834 |
| *Stylocline micropoides* | NA | NA | NA | NA | 0.008 | 0.048 |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.)
Area (ha) of each subhabitat is: Total - 273.5; LAH-70.7; LA - 155.4; LAC - 24.6; and Wash - 0.23.

** In 1990, LAC quadrats were duplicated, and 14 LAH-quadrats were duplicated at random to standardize sampling.
Resulting in 134 total quadrats.
In 1991, each wash quadrat was multiplied by 10 to correct for the area of the original quadrats relative to other sampling.
In 1992, some quadrats were duplicated to standardize sampling: LA = 16; LAC = 8; and Wash = 6.
Resulting in 177 total quadrats.

*** *Bromus spp. - B. rubens and B. tectorum*

Appendix VI. Frequencies of plant occurrence on quadrats for the City Creek Site (A - C) and, the Littlefield Site (D - F) in 1990 - 1992. These adjusted values were used to calculate alpha preference values in selection analyses.

Appendix VI A. Frequencies of plant occurence on 90** quadrats for the City Creek Site, 1990.
Adjusted values were used to calculate alpha preference values in diet selection analyses.
Adjusted frequencies were weighted* and corrected**.

| **SPECIES** | **Dune Raw** | **Adjusted** | **Blackbrush Raw** | **Adjusted** | **Rocky Raw** | **Adjusted** | **Transition Raw** | **Adjusted** | **Total Adjusted Frequency Values** |
|---|---|---|---|---|---|---|---|---|---|
| *Bromus spp.* *** | 5 | 5.0 | 18 | 12.8 | 9 | 18.6 | 13 | 2.9 | 39 |
| *Cryptantha spp.* *** | 4 | 0.9 | 0 | 0.0 | 2 | 4.1 | 0 | 0.0 | 5 |
| *Cryptantha micrantha* | 6 | 1.4 | 0 | 0.0 | 0 | 0.0 | 6 | 5.9 | 7 |
| *Descurainia pinnata* | 0 | 0.0 | 0 | 0.0 | 1 | 2.1 | 2 | 0.5 | 3 |
| *Erodium cicutarium* | 0 | 0.0 | 12 | 8.5 | 4 | 8.3 | 10 | 2.3 | 19 |
| *Eriastrum eremicum* | 1 | 1.0 | 0 | 0.0 | 1 | 2.1 | 2 | 0.5 | 4 |
| *Eriophyllum wallacei* | 3 | 3.0 | 0 | 0.0 | 0 | 0.0 | 14 | 3.2 | 6 |
| *Euphorbia parryi* | 3 | 3.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 |
| *Gilia spp.* *** | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 0 |
| *Gilia sp.* | 0 | 0.0 | 0 | 0.0 | 1 | 2.1 | 2 | 0.5 | 3 |
| *Lepidium flavum* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Lepidium flavum* | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Microcereus lindleyi* | 0 | 0.0 | 0 | 0.0 | 1 | 2.1 | 0 | 0.0 | 2 |
| *Pectocarya recurvata* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Phacelia ivesiana* | 3 | 3.0 | 0 | 0.0 | 0 | 0.0 | 2 | 0.5 | 3 |
| *Plantago spp.* *** | 0 | 0.0 | 1 | 0.7 | 1 | 2.1 | 0 | 0.0 | 3 |
| *Schismus barbatus* | 2 | 2.0 | 6 | 4.3 | 0 | 0.0 | 14 | 3.2 | 9 |
| *Silene antirrhina* | 0 | 0.0 | 0 | 0.0 | 1 | 2.1 | 0 | 0.0 | 2 |
| *Stephanomeria exigua* | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Thysanocarpus cuneifolia* | 0 | 0.0 | 0 | 0.0 | 2 | 4.1 | 0 | 0.0 | 4 |

* Weighted values with the following equation: (freq. for quad*area of subhabitat)/total area) *number of subhabitats)
Areas (in hectare) of subhabitats: Total-271.6; Dune-67.3;Rocky-140.7;Trans-15.3;Blackbrush-48.3.

** Corrected values were calculated by subtracting 10 quadrats at random from Transition subhabitat.
Resulting total number of quadrats was 80.

*** *Bromus spp. - B. rubens and B. tectorum; Cryptantha spp. - C. angustifolia, C. nevadensis, C. virginensis;*
*Gilia spp. - G. scopulorum, and G. leptomeria; Plantago spp. - P. patagonica, P. insularis.*

Appendix VI B. Frequencies of plant occurence on 145** quadrats for the City Creek Site,1991.
s were used to calculate alpha preference values in diet selection analyses.
Adjusted frequencies were weighted* and corrected**.

| SPECIES | Dune Raw | Adjusted | Blackbrush Raw | Adjusted | Rocky Raw | Adjusted | Transition Raw | Adjusted | Total Adjusted Frequency Values |
|---|---|---|---|---|---|---|---|---|---|
| *Amsinckia tesselata* | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 1 |
| *Astragalus nuttaliannus* | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Bromus spp.**** | 1 | 1.0 | 21 | 14.9 | 24 | 49.7 | 14 | 3.2 | 69 |
| *Camissonia andina* | 20 | 19.8 | 0 | 0.0 | 0 | 0.0 | 2 | 0.5 | 20 |
| *Chorizanthe brevicornu* | 0 | 0.0 | 4 | 2.8 | 6 | 12.4 | 0 | 0.0 | 15 |
| *Chorizanthe thurberi* | 0 | 0.0 | 4 | 2.8 | 2 | 4.1 | 5 | 1.1 | 8 |
| *Cryptantha spp.**** | 3 | 3.0 | 12 | 8.5 | 12 | 24.9 | 5 | 1.1 | 38 |
| *Cryptantha micrantha* | 17 | 16.8 | 0 | 0.0 | 0 | 0.0 | 16 | 3.6 | 20 |
| *Descurainia pinnata* | 9 | 8.9 | 4 | 2.8 | 4 | 8.3 | 20 | 4.5 | 25 |
| *Dithyrea wislizenii* | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 3 | 0.7 | 2 |
| *Draba sp.* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Draba cuneifolia* | 0 | 0.0 | 9 | 6.4 | 10 | 20.7 | 0 | 0.0 | 27 |
| *Erodium cicutarium* | 1 | 1.0 | 17 | 12.1 | 8 | 16.6 | 14 | 3.2 | 33 |
| *Eriastrum eremicum* | 1 | 1.0 | 9 | 6.4 | 2 | 4.1 | 16 | 3.6 | 15 |
| *Eriogonum thomasii* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 | 0.7 | 1 |
| *Eriophyllum wallacei* | 8 | 7.9 | 7 | 5.0 |  | 0.0 | 30 | 6.8 | 20 |
| *Euphorbia parryi* | 2 | 2.0 | 1 | 0.7 | 0 | 0.0 | 1 | 0.2 | 3 |
| *Gilia leptomeria* | 5 | 5.0 | 7 | 5.0 | 6 | 12.4 | 2 | 0.5 | 23 |
| *Hymenoxis filifolia* | 1 | 1.0 | 0 | 0.0 | 0 | 0.0 | 2 | 0.5 | 1 |

* Weighted values were arrived at with the following equation:
(freq. for quad*area of subhabitat)/total area) *number of subhabitats)
Areas (in hectare) of subhabitats: Total-271.6; Dune-67.3;Rocky-140.7;Trans-15.3;Blackbrush-48.3.

** Corrected values were calculated by duplicating Rocky subhabitat quadrats. Resulted in 167 total quadrat values.

*** *Bromus spp. - B. rubens and B. tectorum; Cryptantha spp. - C. angustifolia, C. nevadensis, C. virginensis;*
*Gilia spp. - G. scopulorum, and G. leptomeria; Plantago spp. - P. patagonica, P. insularis.*

Appendix VI B. (Continued)

| **SPECIES** | **Dune Raw** | **Adjusted** | **Blackbrush Raw** | **Adjusted** | **Rocky Raw** | **Adjusted** | **Transition Raw** | **Adjusted** | **Total Frequency Values** |
|---|---|---|---|---|---|---|---|---|---|
| *Linanthus sp.* | 0 | 0.0 | 1 | 0.7 | 2 | 4.1 | 0 | 0.0 | 5 |
| *Mentzelia albicaulis* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Microcereus lindleyi* | 0 | 0.0 | 2 | 1.4 | 2 | 4.1 | 0 | 0.0 | 6 |
| *Pectocarya recurvata* | 0 | 0.0 | 16 | 11.4 | 6 | 12.4 | 14 | 3.2 | 27 |
| *Phacelia bicolor* | 0 | 0.0 | 1 | 0.7 | 2 | 4.1 | 0 | 0.0 | 5 |
| *Phacelia ivesiana* | 4 | 4.0 | 1 | 0.7 | 6 | 12.4 | 4 | 0.9 | 18 |
| *Plantago insularis* | 0 | 0.0 | 26 | 18.5 | 24 | 49.7 | 9 | 2.0 | 70 |
| *Salsola iberica* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 0 |
| *Schismus barbatus* | 7 | 6.9 | 19 | 13.5 | 18 | 37.3 | 25 | 5.6 | 63 |
| *Stephanomeria exigua* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *Streptanthella longirostris* | 14 | 13.9 | 1 | 0.7 | 2 | 4.1 | 4 | 0.9 | 20 |
| *Stylocline micropoides* | 0 | 0.0 | 4 | 2.8 | 0 | 0.0 | 3 | 0.7 | 4 |

* Values weighted by the following calculation: (biomass value for quad*area of subhabitat)/total area) *number of subhabitats).

** Values corrected by duplicating quadrat values for Rocky subhabitat.

*** *Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.*

Appendix VI C. Frequencies of plant occurence on 119** quadrats for the City Creek Site, 1992.
Adjusted values were used to calculate alpha preference values in diet selection analyses.
Adjusted frequencies were weighted* and corrected**.

| **SPECIES** | **Dune Raw** | **Adjusted** | **Blackbrush Raw** | **Adjusted** | **Rocky Raw** | **Adjusted** | **Transition Raw** | **Adjusted** | **Total Adjusted Frequency Values** |
|---|---|---|---|---|---|---|---|---|---|
| *Astragalus nuttaliannus* | 0 | 0.0 | 2 | 1.4 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Bromus spp.* *** | 15 | 14.9 | 38 | 27.0 | 20 | 41.4 | 41 | 9.2 | 93 |
| *Chorizanthe brevicornu* | 0 | 0.0 | 9 | 6.4 | 0 | 0.0 | 2 | 0.5 | 7 |
| *Chorizanthe thurberi* | 0 | 0.0 | 9 | 6.4 | 0 | 0.0 | 7 | 1.6 | 8 |
| *Corydalis aurea* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 0 |
| *Cryptantha spp.**** | 20 | 19.8 | 7 | 5.0 | 11 | 22.8 | 24 | 5.4 | 53 |
| *Cryptantha micrantha* | 32 | 31.7 | 22 | 15.6 | 0 | 0.0 | 25 | 5.6 | 53 |
| *Dexcurainia pinnata* | 28 | 27.8 | 11 | 7.8 | 0 | 0.0 | 36 | 8.1 | 44 |
| *Draba cuneifolia* | 0 | 0.0 | 12 | 8.5 | 0 | 0.0 | 7 | 1.6 | 10 |
| *Erodium cicutarium* | 5 | 5.0 | 34 | 24.2 | 10 | 20.7 | 32 | 7.2 | 57 |
| *Eriastrum diffusum* | 0 | 0.0 | 5 | 3.6 | 0 | 0.0 | 5 | 1.1 | 5 |
| *Erisatrum eremicum* | 3 | 3.0 | 6 | 4.3 | 0 | 0.0 | 21 | 4.7 | 12 |
| *Eriogonum maculatum* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 3 | 0.7 | 1 |
| *Eriogonum nidularium* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 1 | 0.2 | 1 |
| *Eriogonum thomasii* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 0 |
| *Eriogonum wallacei* | 11 | 10.9 | 6 | 4.3 | 0 | 0.0 | 32 | 7.2 | 22 |
| *Euphorbia parryi* | 3 | 3.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3 |
| *Festuca octoflora* | 26 | 25.8 | 25 | 17.8 | 8 | 16.6 | 35 | 7.9 | 68 |
| *Gilia spp.**** | 13 | 12.9 | 19 | 13.5 | 0 | 0.0 | 4 | 0.9 | 27 |
| *Langloisia setosissima* | 0 | 0.0 | 1 | 0.7 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Lepidium flavum* | 0 | 0.0 | 13 | 9.2 | 0 | 0.0 | 3 | 0.7 | 10 |
| *Linanthus sp.* | 0 | 0.0 | 4 | 2.8 | 0 | 0.0 | 4 | 0.9 | 4 |
| *Lotus plebieus* | 4 | 4.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 4 |

* Values weighted by the following calculation:
(biomass value for quad*area of subhabitat)/total area) *number of subhabitats).

** Values corrected by duplicating quadrat values for Rocky subhabitat. Resulting in 150 total quadrats.

*** Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.

Appendix VI C. (Continued).

| | Dune | | Blackbrush | | Rocky | | Transition | | Total Adjusted Frequency |
|---|---|---|---|---|---|---|---|---|---|
| **SPECIES** | **Raw** | **Adjusted** | **Raw** | **Adjusted** | **Raw** | **Adjusted** | **Raw** | **Adjusted** | **Values** |
| *Plantago insularis* | 0 | 0.0 | 35 | 24.9 | 14 | 29.0 | 16 | 3.6 | 58 |
| *Schismus barbatus* | 0 | 0.0 | 10 | 7.1 | 2 | 4.1 | 24 | 5.4 | 17 |
| *Silene antirrhina* | 0 | 0.0 | 1 | 0.7 | 4 | 8.3 | 3 | 0.7 | 10 |
| *Stephanomeria exigua* | 8 | 7.9 | 2 | 1.4 | 2 | 4.1 | 8 | 1.8 | 15 |
| *Streptanthella longirostris* | 30 | 29.7 | 1 | 0.7 | 0 | 0.0 | 16 | 3.6 | 34 |
| *Stylocline micropoides* | 0 | 0.0 | 2 | 1.4 | 0 | 0.0 | 7 | 1.6 | 3 |

* Values weighted by the following calculation:
(biomass value for quad*area of subhabitat)/total area) *number of subhabitats).

** Values corrected by duplicating quadrat values for Rocky subhabitat.

*** Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.

Appendix VI D. Frequencies of plant occurence on 126** quadrats for the Littlefield Site, 1990.
Adjusted vpha preference values in diet selection analyses.
Adjusted fwere weighted* and corrected**.

| SPECIES | Dune Raw | Adjusted | Blackbrush Raw | Adjusted | Rocky Raw | Adjusted | Transition Raw | Adjusted | Total Adjusted Frequency Values |
|---|---|---|---|---|---|---|---|---|---|
| *Bromus spp.* *** | 37 | 84.1 | 26 | 9.4 | 41 | 42.4 | 36 | 0.1 | 136 |
| *Chorizanthe brevicornu* | 5 | 11.4 | 2 | 0.7 | 0 | 0.0 | 1 | 0.0 | 12 |
| *Descurainia pinnata* | 37 | 84.1 | 4 | 1.4 | 0 | 0.0 | 2 | 0.0 | 86 |
| *Erodium cicutarium* | 0 | 0.0 | 16 | 5.8 | 21 | 21.7 | 19 | 0.1 | 28 |
| *Eriastrum eremicum* | 0 | 0.0 | 0 | 0.0 | 12 | 12.4 | 0 | 0.0 | 12 |
| *Eriogonum thomasii* | 9 | 20.5 | 18 | 6.5 | 37 | 38.3 | 4 | 0.0 | 65 |
| *Euphorbia micromera* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2 | 0.0 | 0 |
| *Lepidium flavum* | 6 | 13.6 | 2 | 0.7 | 4 | 4.1 | 2 | 0.0 | 18 |
| *Lesquerella tenella* | 5 | 11.4 | 8 | 2.9 | 0 | 0.0 | 1 | 0.0 | 14 |
| *Lotus sp.* | 1 | 2.3 | 0 | 0.0 | 2 | 2.1 | 0 | 0.0 | 4 |
| *Monoptilon bellioides* | 3 | 6.8 | 10 | 3.6 | 11 | 11.4 | 1 | 0.0 | 22 |
| *Pectocarya recurvata* | 0 | 0.0 | 2 | 0.7 | 0 | 0.0 | 1 | 0.0 | 1 |
| *Plantago spp.* *** | 24 | 54.5 | 38 | 13.7 | 40 | 41.4 | 7 | 0.0 | 110 |
| *Schismus barbatus* | 38 | 86.4 | 38 | 13.7 | 40 | 41.4 | 21 | 0.1 | 141 |

* Values weighted by the following calculation: (biomass value for quad*area of subhabitat)/total area) *number of subhabitats).
Areas of the subhabitats were:Total-273.5; LA-155.4;lac-24.6;LAH-70.7;Wash-0.23.

** Data were corrected as: LAC values were duplicated and 14 LAH quadrats were duplicated at random.
were duplicated randomly in LAH subhabitat to standardize sampling. Resulting in 134 total quadrats.
Parts of transect #101 were deleted so that the data were comparable to other transect data.

*** Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.

Appendix VI E. Frequencies of plant occurence on 148** quadrats for the Littlefield Site,1991.
Adjusted values were used to calculate alpha preference values in diet selection analyses.
Adjusted frequencies were weighted* and corrected**.

| **SPECIES** | **Dune Raw** | **Adjusted** | **Blackbrush Raw** | **Adjusted** | **Rocky Raw** | **Adjusted** | **Transition Raw** | **Adjusted** | **Total Adjusted Frequency Values** |
|---|---|---|---|---|---|---|---|---|---|
| *Astragalus nuttaliannus* | 2 | 4.5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 5 |
| *Bromus spp.* *** | 29 | 65.9 | 23 | 8.3 | 26 | 26.9 | 19 | 0.1 | 101 |
| *Chorizanthe brevicornu* | 1 | 2.3 | 0 | 0.0 | 0 | 0.0 | 9 | 0.0 | 2 |
| *Chorizanthe rigida* | 0 | 0.0 | 3 | 1.1 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Descurainia pinnata* | 8 | 18.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 18 |
| *Draba cuneifolia* | 1 | 2.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2 |
| *Erodium cicutarium* | 31 | 70.5 | 4 | 1.4 | 19 | 19.6 | 0 | 0.0 | 92 |
| *Erodium texanum* | 4 | 9.1 | 0 | 0.0 | 1 | 1.0 | 0 | 0.0 | 10 |
| *Eriastrum eremicum* | 1 | 2.3 | 0 | 0.0 | 11 | 11.4 | 0 | 0.0 | 14 |
| *Eriogonum thomasii* | 16 | 36.4 | 11 | 4.0 | 24 | 24.8 | 0 | 0.0 | 65 |
| *Langloisia setosissima* | 0 | 0.0 | 3 | 1.1 | 0 | 0.0 | 0 | 0.0 | 1 |
| *Lepidium flavum* | 12 | 27.3 | 4 | 1.4 | 0 | 0.0 | 3 | 0.0 | 29 |
| *Lesquerella tenella* | 4 | 9.1 | 14 | 5.0 | 0 | 0.0 | 0 | 0.0 | 14 |
| *Monoptilon bellioides* | 27 | 61.4 | 11 | 4.0 | 9 | 9.3 | 1 | 0.0 | 75 |
| *Oenothera primaverus* | 1 | 2.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2 |
| *Pectocarya recurvata* | 4 | 9.1 | 3 | 1.1 | 2 | 2.1 | 1 | 0.0 | 12 |
| *Phacelia ivesiana* | 0 | 0.0 | 5 | 1.8 | 2 | 2.1 | 0 | 0.0 | 4 |
| *Plantago spp.* *** | 31 | 70.5 | 27 | 9.7 | 30 | 31.0 | 6 | 0.0 | 111 |
| *Schismus barbatus* | 38 | 86.4 | 33 | 11.9 | 36 | 37.2 | 18 | 0.1 | 136 |

* Values weighted by the following calculation: (biomass value for quad*area of subhabitat)/total area) *number of subhabitats).
Areas of the subhabitats were:Total-273.5; LA-155.4;lac-24.6;LAH-70.7;Wash-0.23.

** Each wash quadrat value was multiplied by 10 to correct for the area of the quadrats relative to other sampling.

*** Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.

Appendix VI F. Frequencies of plant occurence on 147** quadrats for the Littlefield Site,1992.
Adjusted values were used to calculate alpha preference values in diet selection analyses.
Adjusted frequencies were weighted* and corrected**.

| SPECIES | Dune Raw | Adjusted | Blackbrush Raw | Adjusted | Rocky Raw | Adjusted | Transition Raw | Adjusted | Total Adjusted Frequency Values |
|---|---|---|---|---|---|---|---|---|---|
| *Astragalus nuttaliannus* | 7 | 15.9 | 0 | 0.0 | 2 | 2.1 | 0 | 0.0 | 18 |
| *Bromus spp.* *** | 49 | 111.4 | 36 | 13.0 | 45 | 46.5 | 33 | 0.1 | 171 |
| *Chorizanthe brevicornu* | 3 | 6.8 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 7 |
| *Chorizanthe rigida* | 5 | 11.4 | 2 | 0.7 | 1 | 1.0 | 0 | 0.0 | 13 |
| *Descurainia pinnata* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 4 | 0.0 | 0 |
| *Draba cuneifolia* | 2 | 4.5 | 0 | 0.0 | 1 | 1.0 | 3 | 0.0 | 6 |
| *Erodium cicutarium* | 43 | 97.7 | 12 | 4.3 | 26 | 26.9 | 18 | 0.1 | 129 |
| *Eriastrum diffusum* | 0 | 0.0 | 0 | 0.0 | 2 | 2.1 | 0 | 0.0 | 2 |
| *Eriastrum eremicum* | 0 | 0.0 | 0 | 0.0 | 4 | 4.1 | 0 | 0.0 | 4 |
| *Erodium texanum* | 6 | 13.6 | 0 | 0.0 | 3 | 3.1 | 0 | 0.0 | 17 |
| *Eriogonum thomasii* | 21 | 47.7 | 11 | 4.0 | 35 | 36.2 | 3 | 0.0 | 88 |
| *Festuca octoflora* | 7 | 15.9 | 25 | 9.0 | 34 | 35.2 | 0 | 0.0 | 60 |
| *Gilia spp.* *** | 5 | 11.4 | 10 | 3.6 | 4 | 4.1 | 1 | 0.0 | 19 |
| *Hordeum murinum* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.0 | 0 |
| *Langloisia setosissima* | 4 | 9.1 | 9 | 3.2 | 3 | 3.1 | 0 | 0.0 | 15 |
| *Lepidium flavum* | 24 | 54.5 | 3 | 1.1 | 4 | 4.1 | 10 | 0.0 | 60 |
| *Lesquerella tenella* | 8 | 18.2 | 12 | 4.3 | 3 | 3.1 | 3 | 0.0 | 26 |
| *Linanthus dichotomus* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.0 | 0 |
| *Monoptilon bellioides* | 39 | 88.6 | 30 | 10.8 | 24 | 24.8 | 2 | 0.0 | 124 |
| *Pectocarya recurvata* | 10 | 22.7 | 5 | 1.8 | 8 | 8.3 | 2 | 0.0 | 33 |
| *Plantago spp.* *** | 31 | 70.5 | 34 | 12.2 | 53 | 54.8 | 10 | 0.0 | 138 |

* Values weighted by the following calculation: (biomass value for quad*area of subhabitat)/total area) *number of subhabitats). Areas of the subhabitats were:Total-273.5; LA-155.4;lac-24.6;LAH-70.7;Wash-0.23.

** Quadrats were duplicated at random in the following way (LA - 16; LAC - 8 and; Wash 6; Resulting in 177 total quadrats.

*** Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.

Appendix VI F. (Continued)

| | Dune | | Blackbrush | | Rocky | | Transition | | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| **SPECIES** | **Raw** | **Adjusted** | **Raw** | **Adjusted** | **Raw** | **Adjusted** | **Raw** | **Adjusted** | **Values** |
| *Rafinesquia neomexicana* | 0 | 0.0 | 2 | 0.7 | 6 | 6.2 | 0 | 0.0 | 7 |
| *Schismus barbatus* | 45 | 102.3 | 35 | 12.6 | 44 | 45.5 | 33 | 0.1 | 160 |
| *Stephanomeria exigua* | 0 | 0.0 | 1 | 0.4 | 0 | 0.0 | 0 | 0.0 | 0 |
| *Streptanthella longirostris* | 0 | 0.0 | 0 | 0.0 | 3 | 3.1 | 0 | 0.0 | 3 |
| *Stylocline micropoides* | 7 | 15.9 | 0 | 0.0 | 0 | 0.0 | 1 | 0.0 | 16 |

* Values weighted by the following calculation: (biomass value for quad*area of subhabitat)/total area) *number of subhabitats). Areas of the subhabitats were:Total-273.5; LA-155.4;lac-24.6;LAH-70.7;Wash-0.23.

** Quadrats were duplicated at random in the following way (LA - 16; LAC - 8 and; Wash 6; Resulting in 177 total quadrats.

*** Cryptantha spp., Bromus spp., Gilia spp., and Plantago spp. are lumped from raw data.

Appendix VII. Calculations for total mean biomass estimates of annual plants (1990 - 1993) at the City Creek Site (A) and, the Littlefield Site (B). Values were weighted and corrected to standardize sampling*.

Appendix VII A. Calculations for total mean biomass estimates of annual plants at the City Creek Site in 1990 - 1993. Values were weighted* and corrected** to standardize sampling.

| *Year* | *1990* | *1991* | *1992* | *1993* |
|---|---|---|---|---|
| *Total Mean Biomass (g/m^2)* | 0.420 | 3.068 | 11.952 | 13.103 |
| *Standard Deviation* | 1.834 | 7.156 | 14.483 | 15.128 |
| *Number of Quadrats* | N = 90** | N = 165** | N = 150** | N = 162** |
| | *Adjusted Biomass by quadrats* | *Adjusted Biomass by quadrats* | *Adjusted Biomass by quadrats* | *Adjusted Biomass by quadrats* |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.000 | 0.000 |
| | 0.000 | 0.000 | 0.236 | 0.000 |
| | 0.000 | 0.001 | 0.363 | 0.225 |
| | 0.001 | 0.001 | 0.558 | 0.270 |
| | 0.006 | 0.004 | 0.627 | 0.282 |
| | 0.007 | 0.005 | 0.702 | 0.349 |
| | 0.010 | 0.008 | 0.702 | 0.404 |
| | 0.013 | 0.015 | 0.883 | 0.480 |
| | 0.014 | 0.025 | 0.883 | 0.495 |
| | 0.014 | 0.025 | 1.040 | 0.519 |
| | 0.021 | 0.028 | 1.310 | 0.535 |
| | 0.023 | 0.043 | 1.720 | 0.706 |
| | 0.026 | 0.044 | 1.720 | 1.066 |
| | 0.033 | 0.049 | 1.729 | 1.146 |
| | 0.036 | 0.051 | 1.939 | 1.193 |
| | 0.039 | 0.053 | 2.040 | 1.558 |
| | 0.044 | 0.056 | 2.062 | 1.558 |
| | 0.051 | 0.056 | 2.077 | 1.602 |
| | 0.064 | 0.062 | 2.605 | 1.721 |
| | 0.065 | 0.062 | 2.605 | 1.741 |
| | 0.066 | 0.067 | 2.766 | 1.741 |
| | 0.072 | 0.069 | 3.105 | 1.913 |
| | 0.074 | 0.100 | 3.128 | 1.913 |

Appendix VII A. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---|---|---|---|
| 0.080 | 0.113 | 3.208 | 1.931 |
| 0.085 | 0.122 | 3.211 | 2.077 |
| 0.097 | 0.122 | 3.374 | 2.133 |
| 0.098 | 0.135 | 3.401 | 2.660 |
| 0.100 | 0.156 | 3.524 | 2.724 |
| 0.100 | 0.179 | 4.170 | 2.871 |
| 0.108 | 0.182 | 4.279 | 2.983 |
| 0.111 | 0.195 | 4.306 | 2.983 |
| 0.120 | 0.195 | 4.397 | 2.996 |
| 0.130 | 0.206 | 4.397 | 3.037 |
| 0.159 | 0.211 | 4.565 | 3.037 |
| 0.167 | 0.211 | 4.595 | 3.125 |
| 0.176 | 0.213 | 4.816 | 3.125 |
| 0.184 | 0.230 | 4.878 | 3.326 |
| 0.191 | 0.271 | 4.879 | 3.492 |
| 0.191 | 0.271 | 4.889 | 3.492 |
| 0.197 | 0.297 | 5.004 | 3.804 |
| 0.218 | 0.301 | 5.042 | 3.804 |
| 0.224 | 0.305 | 5.350 | 3.885 |
| 0.230 | 0.321 | 5.618 | 3.975 |
| 0.240 | 0.404 | 5.627 | 4.157 |
| 0.299 | 0.404 | 5.700 | 4.425 |
| 0.313 | 0.410 | 5.707 | 4.619 |
| 0.489 | 0.410 | 5.763 | 4.785 |
| 0.503 | 0.424 | 6.167 | 4.785 |
| 0.508 | 0.434 | 6.488 | 4.806 |
| 0.510 | 0.448 | 6.492 | 4.899 |
| 0.516 | 0.486 | 6.547 | 4.899 |
| 0.534 | 0.494 | 6.609 | 4.944 |
| 0.558 | 0.502 | 6.622 | 4.944 |
| 0.650 | 0.547 | 6.899 | 5.620 |
| 0.718 | 0.554 | 7.071 | 5.620 |
| 0.727 | 0.611 | 7.101 | 5.729 |
| 0.738 | 0.617 | 7.324 | 6.487 |
| 0.750 | 0.625 | 7.398 | 6.593 |
| 0.901 | 0.634 | 7.512 | 6.749 |
| 0.938 | 0.646 | 8.251 | 6.827 |
| 0.957 | 0.668 | 8.491 | 6.827 |
| 1.028 | 0.695 | 8.569 | 7.043 |
| 1.713 | 0.712 | 8.607 | 7.043 |
| 16.374 | 0.719 | 8.682 | 7.163 |
|  | 0.751 | 8.782 | 7.193 |
|  | 0.796 | 8.888 | 7.276 |
|  | 0.800 | 9.016 | 7.306 |
|  | 0.819 | 9.027 | 7.354 |

Appendix VII A. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---|---|---|---|
| | 0.819 | 9.096 | 7.626 |
| | 0.835 | 9.157 | 8.181 |
| | 0.851 | 9.157 | 8.181 |
| | 0.858 | 9.377 | 8.199 |
| | 0.858 | 9.377 | 8.893 |
| | 0.859 | 9.421 | 9.019 |
| | 0.886 | 9.423 | 9.019 |
| | 0.952 | 9.646 | 9.048 |
| | 1.023 | 10.137 | 9.103 |
| | 1.071 | 10.137 | 9.142 |
| | 1.071 | 10.251 | 9.142 |
| | 1.071 | 10.307 | 9.282 |
| | 1.114 | 10.344 | 9.285 |
| | 1.117 | 10.573 | 9.870 |
| | 1.117 | 10.597 | 9.899 |
| | 1.127 | 10.838 | 10.213 |
| | 1.240 | 10.896 | 10.213 |
| | 1.242 | 11.186 | 10.653 |
| | 1.393 | 11.206 | 11.123 |
| | 1.416 | 11.255 | 11.270 |
| | 1.501 | 11.316 | 11.641 |
| | 1.593 | 11.383 | 11.641 |
| | 1.615 | 11.389 | 11.735 |
| | 1.654 | 11.813 | 11.972 |
| | 1.677 | 11.952 | 12.191 |
| | 1.738 | 12.077 | 12.548 |
| | 1.745 | 12.152 | 13.484 |
| | 1.852 | 12.408 | 13.975 |
| | 1.857 | 12.643 | 14.051 |
| | 1.857 | 12.793 | 14.297 |
| | 1.871 | 14.150 | 14.689 |
| | 1.901 | 14.483 | 15.288 |
| | 1.903 | 14.836 | 17.903 |
| | 1.942 | 15.069 | 18.150 |
| | 1.944 | 15.343 | 18.424 |
| | 1.972 | 15.527 | 18.663 |
| | 1.991 | 15.711 | 19.241 |
| | 2.198 | 18.444 | 19.506 |
| | 2.263 | 18.572 | 19.985 |
| | 2.265 | 18.636 | 19.985 |
| | 2.289 | 18.827 | 20.270 |
| | 2.309 | 18.913 | 21.252 |
| | 2.590 | 19.139 | 21.580 |
| | 2.593 | 19.739 | 23.158 |
| | 2.707 | 20.397 | 23.264 |

Appendix VII A. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---|---|---|---|
|  | 2.780 | 20.497 | 23.642 |
|  | 2.802 | 22.377 | 24.684 |
|  | 2.845 | 22.377 | 25.506 |
|  | 2.845 | 22.570 | 25.696 |
|  | 2.980 | 23.283 | 25.842 |
|  | 3.284 | 27.122 | 27.784 |
|  | 3.530 | 28.722 | 27.833 |
|  | 3.648 | 32.672 | 27.833 |
|  | 3.653 | 34.081 | 29.017 |
|  | 3.758 | 34.418 | 30.687 |
|  | 3.988 | 34.731 | 31.066 |
|  | 3.990 | 38.773 | 35.029 |
|  | 4.216 | 39.013 | 35.442 |
|  | 4.447 | 42.582 | 35.442 |
|  | 4.828 | 43.478 | 36.068 |
|  | 4.828 | 44.093 | 36.321 |
|  | 5.268 | 50.828 | 36.321 |
|  | 5.309 | 51.798 | 38.256 |
|  | 5.380 | 58.371 | 38.387 |
|  | 5.471 | 61.233 | 40.017 |
|  | 5.629 | 61.868 | 41.634 |
|  | 5.707 | 63.096 | 41.634 |
|  | 5.904 | 75.050 | 42.897 |
|  | 6.458 |  | 44.411 |
|  | 8.917 |  | 44.411 |
|  | 11.566 |  | 46.062 |
|  | 11.834 |  | 46.062 |
|  | 13.330 |  | 48.621 |
|  | 14.150 |  | 48.621 |
|  | 16.093 |  | 51.712 |
|  | 16.701 |  | 62.389 |
|  | 22.147 |  | 62.389 |
|  | 25.162 |  | 73.669 |
|  | 26.771 |  |  |
|  | 31.041 |  |  |
|  | 35.703 |  |  |
|  | 35.703 |  |  |
|  | 49.253 |  |  |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.)
Areas of Subhabitats: Dune = 67.33 ha, Blackbrush = 48.29 ha,
Rocky = 140.7 ha, Trans = 15.3 ha.; Total area = 271.62 ha.

Appendix VII A. (Continued)

** In 1990, 10 quadrats were eliminated at random to standardize the sampling.
As a result, there were a total of 80 quadrats.
In 1991 values for Rocky subhabitat were duplicated to standardize sampling.
As a result, there were a total of 167 quadrats.
In 1992 values for Rocky subhabitat were duplicated to standardize sampling.
As a result, there were a total of 150 quadrats.

Appendix VII B. Calculations for total mean biomass estimates of annual plants at the Littlefield Site in 1990 - 1993. Values were weighted* and corrected** to standardize sampling.

| *Year* | ***1990*** | ***1991*** | ***1992*** | ***1993*** |
|---|---|---|---|---|
| *Total Mean Biomass (g/m^2)* | **2.43** | **7.58** | **40.08** | **112.81** |
| *Standard Deviation* | **4.12** | **11.25** | **61.83** | **314.94** |
| *Number of Quadrats* | **N = 160** | **N = 148** | **N = 176** | **N = 150** |

| *Adjusted Biomass by quadrats* | *Adjusted Biomass by quadrats* | *Adjusted Biomass by quadrats* | *Adjusted Biomass by quadrats* |
|---|---|---|---|
| 0.000 | 0.000 | 0.000 | 28.310 |
| 0.000 | 0.000 | 0.000 | 33.082 |
| 0.000 | 0.000 | 0.000 | 37.564 |
| 0.000 | 0.000 | 0.002 | 38.928 |
| 0.000 | 0.000 | 0.030 | 43.073 |
| 0.000 | 0.000 | 0.034 | 48.410 |
| 0.000 | 0.000 | 0.034 | 48.983 |
| 0.000 | 0.000 | 0.045 | 50.037 |
| 0.001 | 0.000 | 0.046 | 50.910 |
| 0.001 | 0.000 | 0.052 | 51.319 |
| 0.001 | 0.001 | 0.055 | 53.592 |
| 0.001 | 0.002 | 0.077 | 55.801 |
| 0.002 | 0.003 | 0.100 | 60.374 |
| 0.003 | 0.003 | 0.104 | 66.719 |
| 0.004 | 0.004 | 0.120 | 73.237 |
| 0.004 | 0.004 | 0.120 | 74.819 |
| 0.004 | 0.005 | 0.134 | 75.101 |
| 0.004 | 0.006 | 0.136 | 75.137 |
| 0.007 | 0.007 | 0.148 | 77.619 |
| 0.011 | 0.007 | 0.148 | 86.319 |
| 0.012 | 0.007 | 0.155 | 87.001 |
| 0.012 | 0.008 | 0.177 | 91.974 |
| 0.012 | 0.008 | 0.216 | 95.665 |
| 0.012 | 0.010 | 0.219 | 118.011 |
| 0.013 | 0.010 | 0.219 | 135.147 |
| 0.014 | 0.011 | 0.226 | 211.203 |
| 0.014 | 0.011 | 0.253 | 211.339 |
| 0.016 | 0.018 | 0.253 | 217.003 |
| 0.018 | 0.024 | 0.338 | 247.785 |
| 0.018 | 0.029 | 0.343 | 248.167 |
| 0.019 | 0.031 | 0.353 | 415.833 |
| 0.020 | 0.031 | 0.354 | 483.553 |
| 0.021 | 0.031 | 0.420 | 645.373 |
| 0.022 | 0.036 | 0.422 | 674.046 |
| 0.023 | 0.038 | 0.422 | 825.976 |
| 0.024 | 0.038 | 0.456 | 934.586 |
| 0.026 | 0.040 | 0.539 | 1170.508 |
| 0.027 | 0.058 | 0.539 | 1342.838 |
| 0.029 | 0.075 | 0.543 | 1357.747 |

Appendix VII B. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---|---|---|---|
| 0.030 | 0.087 | 0.566 | 2817.632 |
| 0.030 | 0.098 | 0.566 | 3.083 |
| 0.032 | 0.106 | 0.580 | 3.647 |
| 0.032 | 0.122 | 0.595 | 4.286 |
| 0.044 | 0.168 | 0.742 | 4.399 |
| 0.048 | 0.223 | 0.742 | 4.479 |
| 0.058 | 0.246 | 0.750 | 5.659 |
| 0.058 | 0.259 | 0.988 | 6.125 |
| 0.099 | 0.284 | 1.014 | 6.335 |
| 0.099 | 0.307 | 1.212 | 8.294 |
| 0.136 | 0.416 | 1.278 | 8.302 |
| 0.151 | 0.455 | 1.482 | 8.422 |
| 0.151 | 0.476 | 1.489 | 8.571 |
| 0.214 | 0.594 | 1.550 | 10.793 |
| 0.223 | 0.599 | 1.550 | 10.832 |
| 0.223 | 0.635 | 2.194 | 11.743 |
| 0.227 | 0.644 | 2.312 | 15.014 |
| 0.230 | 0.661 | 2.312 | 17.982 |
| 0.239 | 0.710 | 2.362 | 18.737 |
| 0.239 | 0.793 | 2.896 | 20.585 |
| 0.287 | 0.847 | 3.129 | 21.594 |
| 0.287 | 0.894 | 3.173 | 21.600 |
| 0.295 | 0.925 | 3.311 | 24.013 |
| 0.308 | 0.962 | 3.433 | 24.055 |
| 0.330 | 1.002 | 3.433 | 28.089 |
| 0.331 | 1.007 | 3.793 | 30.838 |
| 0.336 | 1.075 | 3.858 | 31.108 |
| 0.336 | 1.109 | 5.918 | 32.449 |
| 0.380 | 1.203 | 5.918 | 36.418 |
| 0.398 | 1.470 | 6.850 | 36.878 |
| 0.407 | 1.488 | 7.357 | 37.647 |
| 0.407 | 1.697 | 7.445 | 41.288 |
| 0.408 | 1.762 | 7.514 | 41.601 |
| 0.448 | 1.776 | 7.703 | 43.336 |
| 0.448 | 1.818 | 7.896 | 70.167 |
| 0.457 | 1.907 | 8.447 | 87.645 |
| 0.459 | 2.000 | 8.865 | 9.401 |
| 0.499 | 2.148 | 8.997 | 10.985 |
| 0.502 | 2.300 | 8.997 | 12.230 |
| 0.535 | 2.377 | 9.178 | 12.251 |
| 0.535 | 2.474 | 9.341 | 13.624 |
| 0.549 | 2.594 | 9.341 | 14.286 |
| 0.554 | 3.085 | 9.468 | 14.807 |
| 0.554 | 3.162 | 9.716 | 15.324 |
| 0.568 | 3.240 | 10.350 | 15.659 |

Appendix VII B. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---:|---:|---:|---:|
| 0.641 | 3.339 | 11.486 | 15.924 |
| 0.641 | 3.348 | 12.204 | 16.114 |
| 0.695 | 3.811 | 12.259 | 16.920 |
| 0.698 | 4.229 | 12.814 | 18.926 |
| 0.734 | 4.850 | 15.490 | 19.022 |
| 0.734 | 5.288 | 15.490 | 19.845 |
| 0.747 | 5.545 | 15.734 | 21.627 |
| 0.803 | 5.667 | 15.879 | 21.851 |
| 0.803 | 5.948 | 16.102 | 21.975 |
| 0.804 | 6.355 | 16.597 | 27.376 |
| 0.822 | 7.028 | 17.176 | 28.199 |
| 0.822 | 7.541 | 18.420 | 31.020 |
| 0.834 | 7.561 | 18.917 | 32.985 |
| 0.836 | 7.665 | 19.064 | 35.268 |
| 0.836 | 7.998 | 19.064 | 35.599 |
| 0.950 | 8.655 | 20.786 | 39.838 |
| 1.010 | 8.989 | 20.868 | 42.167 |
| 1.010 | 9.018 | 22.724 | 48.255 |
| 1.119 | 9.280 | 25.389 | 51.365 |
| 1.119 | 9.946 | 26.483 | 58.140 |
| 1.227 | 10.105 | 28.729 | 59.509 |
| 1.375 | 10.457 | 29.252 | 60.361 |
| 1.445 | 10.471 | 31.024 | 81.707 |
| 1.470 | 10.850 | 31.471 | 90.024 |
| 1.603 | 11.159 | 31.803 | 327.403 |
| 1.706 | 11.270 | 31.803 | 328.098 |
| 1.706 | 11.374 | 32.037 | 147.705 |
| 1.739 | 11.971 | 32.077 | 152.751 |
| 1.745 | 11.972 | 32.572 | 166.214 |
| 2.141 | 12.301 | 33.036 | 186.865 |
| 2.273 | 12.523 | 34.021 | 350.589 |
| 2.283 | 13.021 | 36.088 | 0.012 |
| 2.629 | 13.235 | 36.399 | 0.021 |
| 2.639 | 13.276 | 36.873 | 0.024 |
| 2.708 | 13.561 | 37.387 | 0.028 |
| 2.896 | 13.714 | 37.387 | 0.033 |
| 3.034 | 13.787 | 39.864 | 0.035 |
| 3.164 | 14.355 | 40.114 | 0.038 |
| 3.186 | 14.387 | 42.321 | 0.041 |
| 3.589 | 14.660 | 42.436 | 0.043 |
| 3.629 | 14.702 | 42.830 | 0.043 |
| 4.089 | 14.791 | 43.909 | 0.044 |
| 4.168 | 16.047 | 46.443 | 0.045 |
| 4.701 | 17.382 | 46.582 | 0.049 |
| 4.939 | 18.857 | 47.374 | 0.050 |

Appendix VII B. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---|---|---|---|
| 5.019 | 21.541 | 47.471 | 0.053 |
| 5.048 | 21.887 | 49.114 | 0.070 |
| 5.073 | 21.925 | 49.114 | 0.076 |
| 5.221 | 22.562 | 54.648 | 0.077 |
| 5.334 | 23.287 | 55.763 | 0.077 |
| 5.689 | 24.571 | 56.624 | 0.082 |
| 5.761 | 24.779 | 56.624 | 0.085 |
| 6.014 | 24.900 | 58.653 | 0.088 |
| 6.016 | 25.728 | 60.767 | 0.097 |
| 6.032 | 27.264 | 60.767 | 0.122 |
| 6.230 | 29.527 | 62.443 | 0.122 |
| 6.694 | 30.446 | 72.258 | 0.130 |
| 7.109 | 35.058 | 72.258 | 0.131 |
| 7.667 | 36.607 | 73.492 | 0.147 |
| 8.167 | 36.866 | 73.492 | 0.150 |
| 8.495 | 41.060 | 74.537 | 0.156 |
| 9.109 | 47.964 | 79.701 | 0.171 |
| 9.246 | 52.155 | 81.128 | 0.181 |
| 9.316 | 58.639 | 85.799 | 0.193 |
| 9.650 |  | 85.799 | 0.196 |
| 9.834 |  | 86.293 | 0.361 |
| 9.996 |  | 86.601 |  |
| 10.046 |  | 86.601 |  |
| 10.241 |  | 88.797 |  |
| 11.373 |  | 89.012 |  |
| 12.246 |  | 92.710 |  |
| 13.135 |  | 92.710 |  |
| 14.934 |  | 95.043 |  |
| 17.128 |  | 100.583 |  |
| 20.784 |  | 101.542 |  |
| 25.139 |  | 105.861 |  |
|  |  | 108.819 |  |
|  |  | 121.138 |  |
|  |  | 131.250 |  |
|  |  | 131.250 |  |
|  |  | 136.420 |  |
|  |  | 176.959 |  |
|  |  | 176.959 |  |
|  |  | 193.110 |  |
|  |  | 193.110 |  |
|  |  | 218.824 |  |
|  |  | 218.824 |  |
|  |  | 236.808 |  |
|  |  | 266.945 |  |
|  |  | 305.584 |  |

Appendix VII B. (Continued)

| *1990 Adjusted Biomass by quadrats* | *1991 Adjusted Biomass by quadrats* | *1992 Adjusted Biomass by quadrats* | *1993 Adjusted Biomass by quadrats* |
|---|---|---|---|
| | | 308.766 | |
| | | 308.766 | |

* Weighted values = (((quadrat value*area of subhab.)/ttl area)*number of subhab.)
Area (ha) of each subhabitat is: Total - 273.5; LAH-70.7; LA - 155.4;
LAC - 24.6; Wash - 0.23.

** In 1990, LAC quadrats were duplicated, and 14 LAH-quadrats were duplicated at random to standardize sampling. Resulting in 134 total quadrats.
In 1991, each wash quadrat was multiplied by 10 t correct for the area of the original quadrats relative to other sampling.
In 1992, some quadrats were duplicated to standardize sampling:
LA = 16; LAC = 8; WASH =6. Resulting in 177 total quadrats.

Appendix VIII. Analysis of biomass production among subhabitats (1990 - 1992) at the City Creek Site (A) and, the Littlefield Site (B). One-way analysis of variance and subsequently the Fisher's Protected LSD were used to test for individual differences.

Appendix VIII A. Analysis of biomass production among subhabitats at the City Creek Site in 1990 - 1992 using a one-way analysis of variance and subsequently Fisher's Protected LSD.

1990 **Results of one-way analysis of variance.**
DF = 91; F-statistic = 8.582; P-value = .0001

**Results of Post Hoc analysis using Fisher's Protected LSD.**

| *Subhabitat Comparison* * | *F-statistic* | *P-value* |
|---|---|---|
| D - R | 0.403 | 0.3659 |
| D - B | 0.417 | 0.3496 |
| D - T | 1.789 | 0.0001 |
| R - B | 0.014 | 0.9749 |
| R - T | 1.395 | 0.0008 |
| B - T | 1.381 | 0.0009 |

1991 **Results of one-way analysis of variance.**
DF = 144; F-statistic = 6.327; P-value = .0005

**Results of Post Hoc analysis using Fisher's Protected LSD.**

| *Subhabitat Comparison* * | *F-statistic* | *P-value* |
|---|---|---|
| R - B | 2.419 | 0.3988 |
| R - D | 3.650 | 0.1980 |
| R - T | 10.741 | 0.0003 |
| B - D | 1.231 | 0.6035 |
| B - T | 8.322 | 0.0007 |
| D - T | 7.091 | 0.0032 |

1992 **Results of one-way analysis of variance.**
DF = 133; F-statistic = 17.154; P-value = .0001

**Results of Post Hoc analysis using Fisher's Protected LSD.**

| *Subhabitat Comparison* * | *F-statistic* | *P-value* |
|---|---|---|
| R - B | 14.233 | 0.0582 |
| R - D | 19.295 | 0.0116 |
| R - T | 45.417 | 0.0001 |
| B - D | 5.063 | 0.3796 |
| B - T | 31.185 | 0.0001 |
| D - T | 26.122 | 0.0001 |

* Dune (D); Rocky (R); Blackbrush (B); Transition (T)

Appendix VIII B. Analysis of biomass production among subhabitats at the Littlefield Site in 1990 - 1992 using a one-way analysis of variance and subsequently Fisher's Protected LSD.

**1990** **Results of one-way analysis of variance.**
DF = 125; F-statistic = 5.925; P-value = .0008

**Results of Post Hoc analysis using Fisher's Protected LSD.**

| *Subhabitat Comparison* * | *F-statistic* | *P-value* |
|---|---|---|
| LAH - LA | 1.068 | 0.1687 |
| LAH - Wash | 2.422 | 0.0021 |
| LAH - LAC | 3.038 | 0.0004 |
| LA - Wash | 1.354 | 0.0335 |
| LA - LAC | 1.970 | 0.0064 |
| Wash - LAC | 0.616 | 0.3873 |

**1991** **Results of one-way analysis of variance.**
DF = 147; F-statistic = 5.881; P-value = .0008

**Results of Post Hoc analysis using Fisher's Protected LSD.**

| *Subhabitat Comparison* * | *F-statistic* | *P-value* |
|---|---|---|
| LAH - Wash | 1.505 | 0.3777 |
| LAH - LA | 3.297 | 0.0518 |
| LAH - LAC | 6.886 | 0.0001 |
| Wash - LA | 1.791 | 0.2780 |
| Wash - LAC | 5.380 | 0.0019 |
| LA - LAC | 3.589 | 0.0344 |

**1992** **Results of one-way analysis of variance.**
DF = 144; F-statistic = 7.240; P-value = .0001

**Results of Post Hoc analysis using Fisher's Protected LSD.**

| *Subhabitat Comparison* * | *F-statistic* | *P-value* |
|---|---|---|
| LAH - LAC | 7.671 | 0.4723 |
| LAH - LA | 18.106 | 0.1315 |
| LAH - Wash | 47.578 | 0.0001 |
| LAC - LA | 10.435 | 0.3637 |
| LAC - Wash | 39.907 | 0.0002 |
| LA - Wash | 29.472 | 0.0142 |

Appendix IX. Analysis of biomass production in subhabitats compared among years (1990 - 1992) at the City Creek Site (A) and, the Littlefield Site (B). One-way analysis of variance and subsequently the Fisher's Protected LSD were used to test for individual differences among years.

Appendix IX A. Analysis of biomass production in subhabitats compared among years at the City Creek Site in 1990 - 1992 using the one-way analysis of variance and subsequently Fisher's Protected LSD when the analysis of variance was significant.

**DUNE**

**Results of one-way analysis of variance.**
DF = 97; F-statistic = 19.097; P-value = .0001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 4.709 | 0.2249 |
| 90 - 92 | 21.089 | 0.0001 |
| 91 - 92 | 16.38 | 0.0001 |

**ROCKY**

**Results of one-way analysis of variance.**
DF = 57; F-statistic = 1.006; P-value = .3721

**BLACKBRUSH**

**Results of one-way analysis of variance.**
DF = 99; F-statistic = 14.11; P-value = .0001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 3.061 | 0.3806 |
| 90 - 92 | 15.609 | 0.0001 |
| 91 - 92 | 12.548 | 0.0001 |

**TRANSITION**

**Results of one-way analysis of variance.**
DF = 110; F-statistic = 36.573; P-value = .0001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 10.241 | 0.0823 |
| 90 - 92 | 45.652 | 0.0001 |
| 91 - 92 | 35.411 | 0.0001 |

* means for these analyses displayed in Table 3.

Appendix IX B. Analysis of biomass production in subhabitats compared among years at the Littlefield Site in 1990 - 1992 using the one-way analysis of variance and subsequently Fisher's Protected LSD when the analysis of variance was significant.

LA *

**Results of one-way analysis of variance.**
DF = 107; F-statistic = 51.884; P-value = .0001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 4.795 | 0.2834 |
| 90 - 92 | 46.633 | 0.0001 |
| 91 - 92 | 41.838 | 0.0001 |

LAC*

**Results of one-way analysis of variance.**
DF = 90; F-statistic = 14.264; P-value = .001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 2.567 | 0.7093 |
| 90 - 92 | 29.596 | 0.0001 |
| 91 - 92 | 27.029 | 0.0001 |

LAH*

**Results of one-way analysis of variance.**
DF = 104; F-statistic = 32.002; P-value = .0001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 6.414 | 0.208 |
| 90 - 92 | 34.228 | 0.0001 |
| 91 - 92 | 27.814 | 0.0001 |

Wash

**Results of one-way analysis of variance.**
DF = 114; F-statistic = 40.122; P-value = .0001

**Results of Fisher's Protected LSD.**

| *Year Comparison* | *F-statistic* | *P-value* |
|---|---|---|
| 90 - 91 | 1.65 | 0.8605 |
| 90 - 92 | 74.751 | 0.0001 |
| 91 - 92 | 73.101 | 0.0001 |

*

LA: Larrea-Ambrosia association
LAC: Larrea - Ambrosia - Ceratoides Association
LAH: Larrea-Ambrosia - Hilaria Association

Appendix X. Descriptive statistics for spring annual vegetation frequency and mean biomass production among subhabitat types at the City Creek Site in 1989 - 1992 (A - D) and, the Littlefield Site in 1990 - 1992 (E - G).

Appendix X A. Descriptive statistics for spring annual vegetation within four subhabitat types at the City Creek Site in 1989.

| | Frequency | Relative Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|---|
| **DUNE (N = 40)** | | | | |
| *Bromus rubens* | 19 | 0.48 | 0.06 | 0.15 |
| *Bromus tectorum* | 5 | 0.13 | 0.03 | 0.09 |
| *Cryptantha micrantha* | 9 | 0.23 | 0.02 | 0.10 |
| *Erodium cicutarium* | 5 | 0.13 | 0.03 | 0.09 |
| *Eriophyllum wallacii* | 2 | 0.05 | 0.00 | 0.01 |
| *Euphorbia parryi* | 3 | 0.08 | 0.01 | 0.05 |
| *Eriastrum eremicum* | 1 | 0.03 | 0.00 | 0.01 |
| *Plantago patagonica* | 1 | 0.03 | 0.00 | 0.00 |
| *Schismus barbatus* | 1 | 0.03 | 0.00 | 0.01 |
| **TRANSITION (N = 40)** | | | | |
| *Bromus rubens* | 35 | 0.88 | 0.76 | 1.35 |
| *Bromus tectorum* | 17 | 0.43 | 0.25 | 0.55 |
| *Cryptantha micrantha* | 3 | 0.08 | 0.01 | 0.06 |
| *Erodium cicutarium* | 14 | 0.35 | 1.13 | 3.68 |
| *Eriophyllum wallacii* | 15 | 0.38 | 0.02 | 0.05 |
| *Eriastrum eremicum* | 5 | 0.13 | 0.00 | 0.01 |
| *Plantago patagonica* | 2 | 0.05 | 0.00 | 0.00 |
| *Linthanthus sp.* | 1 | 0.03 | 0.01 | 0.04 |
| *Mentzelia albicaulis* | 1 | 0.03 | 0.00 | 0.00 |
| *Schismus barbatus* | 2 | 0.05 | 0.00 | 0.00 |
| **BLACKBRUSH (N=40)** | | | | |
| *Bromus rubens* | 36 | 0.90 | 0.55 | 0.68 |
| *Bromus tectorum* | 20 | 0.50 | 0.22 | 0.65 |
| *Erodium cicutarium* | 2 | 0.05 | 0.00 | 0.02 |
| **ROCKY (N=38)** | | | | |
| *Bromus rubens* | 22 | 0.58 | 0.42 | 0.66 |
| *Bromus tectorum* | 11 | 0.29 | 0.09 | 0.23 |
| *Schismus barbatus* | 1 | 0.03 | 0.00 | 0.00 |

Appendix X B. Descriptive statistics for spring annual vegetation within four subhabitat types at the City Creek Site in 1990.

| | **Frequency** | **Relative Frequency** | **Mean Biomass (g/m^2)** | **Standard Deviation** |
|---|---|---|---|---|
| **DUNE (N=20)** | | | | |
| *Cryptantha micrantha* | 6 | 0.30 | 0.01 | 0.02 |
| *Bromus rubens* | 5 | 0.25 | 0.01 | 0.04 |
| *Eriophyllum wallacei* | 3 | 0.15 | 0.01 | 0.02 |
| *Phacelia ivesiana* | 3 | 0.15 | 0.01 | 0.02 |
| *Schismus barbatus* | 2 | 0.10 | 0.00 | 0.00 |
| *Eriastrum eremicum* | 1 | 0.05 | 0.00 | 0.01 |
| *Lotus plebeius* | 1 | 0.05 | 0.01 | 0.03 |
| *Stephanomeria exigua* | 1 | 0.05 | 0.00 | 0.02 |
| **TRANSITION (N=30)** | | | | |
| *Schismus barbatus* | 24 | 0.80 | 0.29 | 0.64 |
| *Bromus rubens* | 22 | 0.73 | 0.70 | 0.96 |
| *Eriophyllum wallacei* | 22 | 0.73 | 0.09 | 0.12 |
| *Erodium cicutarium* | 13 | 0.43 | 0.45 | 0.85 |
| *Cryptantha micrantha* | 10 | 0.33 | 0.01 | 0.01 |
| *Bromus tectorum* | 6 | 0.20 | 0.01 | 0.04 |
| *Eriastrum eremicum* | 5 | 0.17 | 0.01 | 0.02 |
| *Gilia sp.* | 4 | 0.13 | 0.01 | 0.03 |
| *Cryptantha nevadensis* | 4 | 0.13 | 0.01 | 0.03 |
| *Chorizanthe thurberi* | 3 | 0.10 | 0.04 | * |
| *Phacelia ivesiana* | 3 | 0.10 | 0.01 | 0.03 |
| *Descurainia pinnata* | 2 | 0.07 | 0.01 | 0.04 |
| *Plantago patagonica* | 2 | 0.07 | 0.01 | 0.02 |
| *Eriogonum thomasii* | 1 | 0.03 | 0.00 | 0.02 |
| *Eriogonum maculatum* | 1 | 0.03 | 0.00 | 0.02 |
| *Gilia leptomeria* | 1 | 0.03 | 0.00 | 0.02 |
| *Cryptantha sp.* | 1 | 0.03 | 0.00 | 0.01 |
| **BLACKBRUSH (N=20)** | | | | |
| *Bromus rubens* | 17 | 0.85 | 0.36 | 0.54 |
| *Erodium cicutarium* | 12 | 0.60 | 0.10 | 0.15 |
| *Schismus barbatus* | 6 | 0.30 | 0.01 | 0.01 |
| *Bromus tectorum* | 2 | 0.10 | 0.00 | 0.00 |
| *Lepidium flavum* | 1 | 0.05 | 0.00 | 0.01 |
| *Pectocarya recurvata* | 1 | 0.05 | 0.00 | 0.00 |
| *Plantago patagonica* | 1 | 0.05 | 0.00 | 0.00 |
| Unknown species | 2 | 0.10 | 0.01 | 0.02 |

* no standard deviation is possible when only one value was recorded.

** values were <0.001

Appendix X B. (Continued).

| | Frequency | Relative Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|---|
| **ROCKY (N=20)** | | | | |
| *Bromus rubens* | 9 | 0.45 | 0.25 | 0.87 |
| *Erodium cicutarium* | 4 | 0.20 | 0.14 | 0.60 |
| *Cryptantha virginiana* | 2 | 0.10 | 0.00 | 0.01 |
| *Schismus barbatus* | 2 | 0.10 | 0.00 | 0.01 |
| *Thysanocarpus curvipes* | 2 | 0.10 | 0.00 | 0.01 |
| *Bromus tectorum* | 1 | 0.05 | 0.04 | 0.17 |
| *Cryptantha angustifolia* | 1 | 0.05 | 0.01 | 0.02 |
| *Descurainia pinnata* | 1 | 0.05 | ** | 0.00 |
| *Eriastrum eremicum* | 1 | 0.05 | 0.00 | 0.01 |
| *Gilia sp.* | 1 | 0.05 | 0.00 | 0.01 |
| *Microserus lindleyi* | 1 | 0.05 | 0.00 | 0.02 |
| *Plantago patagonica* | 1 | 0.05 | 0.01 | 0.05 |
| *Silene antirrhina* | 1 | 0.05 | 0.00 | 0.00 |

* no standard deviation is possible when only one value was recorded.

** values were <0.001

Appendix X C. Descriptive statistics for spring annual vegetation within four subhabitat types at the City Creek Site in 1991.

| | Frequency | Relative Frequency | Mean Biomass (g/M^2) | Standard Deviation |
|---|---|---|---|---|
| **TRANSITION (N=40)** | | | | |
| *Amsinckia tessellata* | 1 | 0.03 | 0.14 | 0.85 |
| *Bromus rubens* | 14 | 0.35 | 1.04 | 2.63 |
| *Bromus tectorum* | 1 | 0.03 | 0.00 | 0.02 |
| *Camissonia andina* | 2 | 0.05 | 0.00 | 0.01 |
| *Chorizanthe thurberi* | 5 | 0.13 | 0.01 | 0.03 |
| *Cryptantha micrantha* | 16 | 0.40 | 0.15 | 0.42 |
| *C. nevadensis* | 5 | 0.13 | 0.18 | 0.66 |
| *Descurainia pinnata* | 19 | 0.48 | 5.46 | 10.32 |
| *Dithyrea wislizenii* | 2 | 0.05 | 0.79 | 3.84 |
| *Erodium cicutarium* | 14 | 0.35 | 0.95 | 2.69 |
| *Eriastrum eremicum* | 16 | 0.40 | 0.12 | 0.27 |
| *Eriogonum thomasii* | 3 | 0.08 | 0.33 | 1.89 |
| *Eriophyllum wallacei* | 30 | 0.75 | 0.42 | 0.63 |
| *Euphoria parryi* | 1 | 0.03 | * | * |
| *Gilia leptomeria* | 2 | 0.05 | 0.01 | 0.04 |
| *Microcerus lindleyi* | 2 | 0.05 | 0.06 | 0.29 |
| *Pectocarya recurvata* | 14 | 0.35 | 0.15 | 0.36 |
| *Phacelia ivesiana* | 4 | 0.10 | 0.27 | 1.44 |
| *Plantago insularis* | 9 | 0.23 | 0.15 | 0.76 |
| *Salsola iberica* | 1 | 0.03 | 0.20 | 1.24 |
| *Schismus barbatus* | 25 | 0.63 | 0.79 | 2.43 |
| *Stephanomeria exigua* | 1 | 0.03 | 0.05 | 0.29 |
| *Streptanthella longirostris* | 4 | 0.10 | 0.26 | 0.85 |
| *Stylocline micropoides* | 3 | 0.08 | 0.01 | 0.03 |
| **DUNE (N = 38)** | | | | |
| *Astragalus sp.* | 1 | 0.03 | 0.00 | 0.01 |
| *Bromus tectorum* | 1 | 0.03 | 0.04 | 0.23 |
| *Cryptantha micrantha* | 17 | 0.45 | 0.04 | 0.15 |
| *Cryptantha nevadensis* | 3 | 0.08 | 0.10 | 0.36 |
| *Descurainia pinnata* | 9 | 0.24 | 1.24 | 3.35 |
| *Dithyrea wislizenii* | 1 | 0.03 | 0.01 | 0.06 |
| *Erodium cicutarium* | 1 | 0.03 | 0.00 | 0.01 |
| *Eriastrum eremicum* | 1 | 0.03 | 0.00 | 0.02 |
| *Eriophyllum wallacei* | 8 | 0.21 | 0.08 | 0.28 |
| *Euphorbia parryi* | 2 | 0.05 | 0.00 | 0.00 |
| *Gilia leptomeria* | 5 | 0.13 | 0.05 | 0.16 |
| *Hymenopappus filifolius* | 1 | 0.03 | 0.02 | 0.10 |
| *Phacelia ivesiana* | 4 | 0.11 | 0.21 | 0.66 |
| *Schismus barbatus* | 7 | 0.18 | 0.06 | 0.20 |

* estimated values were < 0.0001

Appendix X C. (Continued).

| | Frequency | Relative Frequency | Mean Biomass (g/M^2) | Standard Deviation |
|---|---|---|---|---|
| **ROCKY (N = 27)** | | | | |
| *Streptanthella longirostris* | 13 | 0.34 | 3.02 | 8.80 |
| Unknown species | 2 | 0.05 | * | 0.00 |
| *Bromus rubens* | 10 | 0.37 | 0.21 | 0.77 |
| *Bromus tectorum* | 3 | 0.11 | 0.57 | 2.46 |
| *Chorizanthe brevicornu* | 3 | 0.11 | 0.01 | 0.02 |
| *Chorizanthe thurberi* | 1 | 0.04 | * | 0.00 |
| *Cryptantha angustifolia* | 1 | 0.04 | 0.01 | 0.06 |
| *Cryptantha nevadensis* | 5 | 0.19 | 0.15 | 0.67 |
| *Descurainia pinnata* | 2 | 0.07 | 0.01 | 0.06 |
| *Draba cuneifolia* | 5 | 0.19 | 0.01 | 0.03 |
| *Erodium cicutarium* | 5 | 0.19 | 0.09 | 0.40 |
| *Eriastrum eremicum* | 3 | 0.11 | 0.01 | 0.02 |
| *Linanthus sp.* | 1 | 0.04 | 0.00 | 0.00 |
| *Microcerus lindleyi* | 1 | 0.04 | 0.00 | 0.01 |
| *Pectocarya recurvata* | 3 | 0.11 | 0.02 | 0.07 |
| *Phacelia bicolor* | 1 | 0.04 | 0.00 | 0.01 |
| *Phacelia ivesiana* | 2 | 0.07 | 0.01 | 0.03 |
| *Plantago insularis* | 11 | 0.41 | 0.16 | 0.58 |
| *Plantago patagonica* | 2 | 0.07 | 0.00 | 0.02 |
| *Schismus barbatus* | 9 | 0.33 | 0.03 | 0.05 |
| *Stylocline micropoides* | 3 | 0.11 | 0.03 | 0.14 |
| Unknown species | 1 | 0.04 | * | * |
| **BLACKBRUSH (N = 40)** | | | | |
| *Bromus rubens* | 21 | 0.53 | 0.53 | 1.11 |
| *Bromus tectorum* | 1 | 0.03 | 0.02 | 0.10 |
| *Chorizanthe brevicornu* | 4 | 0.10 | 0.09 | 0.33 |
| *Chorizanthe thurberi* | 4 | 0.10 | 0.04 | 0.14 |
| *Cryptantha micrantha* | 1 | 0.03 | 0.00 | 0.00 |
| *Cryptantha nevadensis* | 2 | 0.05 | 0.03 | 0.12 |
| *Descurainia pinnata* | 4 | 0.10 | 2.00 | 8.79 |
| *Draba sp.* | 1 | 0.03 | 0.00 | 0.00 |
| *Draba cuneifolia* | 9 | 0.23 | 0.02 | 0.08 |
| *Erodium cicutarium* | 17 | 0.43 | 0.73 | 1.99 |
| *Eriastrum eremicum* | 9 | 0.23 | 0.02 | 0.07 |
| *Eriophyllum wallacei* | 7 | 0.18 | 0.01 | 0.02 |
| *Euphorbia parryi* | 1 | 0.03 | 0.00 | 0.00 |
| *Gilia leptomeria* | 7 | 0.18 | 0.01 | 0.04 |
| *Lepidium flavum* | 2 | 0.05 | 0.02 | 0.14 |
| *Linanthus* | 1 | 0.03 | 0.00 | 0.01 |
| *Mentzelia albicaulis* | 1 | 0.03 | 0.02 | 0.14 |
| *Microcerus lindleyi* | 2 | 0.05 | 0.01 | 0.04 |
| *Pectocarya recurvata* | 16 | 0.40 | 0.14 | 0.28 |

Appendix X C. (Continued).

| | | | | |
|---|---|---|---|---|
| *Phacelia bicolor* | 1 | 0.03 | 0.00 | 0.01 |
| *Phacelia ivesiana* | 1 | 0.03 | 0.01 | 0.04 |
| *Plantago insularis* | 26 | 0.65 | 0.21 | 0.34 |
| *Schismus barbatus* | 20 | 0.50 | 0.16 | 0.58 |
| *Stylocline micropoides* | 4 | 0.10 | 0.01 | 0.03 |
| Unknown species | 2 | 0.05 | 0.01 | 0.03 |

* estimated values were < 0.0001

Appendix X D. Descriptive statistics for spring annual vegetation within four subhabitat types at the City Creek Site in 1992.

| **DUNE (N = 35)** | **Frequency** | **Mean Biomass (g/m^2)** | **Standard Deviation** |
|---|---|---|---|
| *Bromus rubens* | 7 | 0.09 | 0.25 |
| *Bromus tectorum* | 10 | 0.44 | 2.09 |
| *Cryptantha micrantha* | 31 | 0.28 | 0.61 |
| *Cryptantha nevadensis* | 1 | na | na |
| *Cryptantha virginensis* | 16 | na | na |
| *Cryptantha sp.* | 3 | 0.49 | 1.00 |
| *Descurainaia pinnnata* | 28 | 1.17 | 2.30 |
| *Erodium cicutarium* | 5 | 0.88 | 3.14 |
| *Eriastrum eremicum* | 3 | 0.00 | 0.02 |
| *Eriophyllum wallacei* | 11 | 0.13 | 0.40 |
| *Euphorbia parryi* | 3 | 0.00 | 0.00 |
| *Festuca octoflora* | 26 | 0.29 | 0.51 |
| *Gilia scopulorum* | 2 | 0.01 | 0.04 |
| *Gilia leptomeria* | 11 | 0.04 | 0.09 |
| *Lotus plebeius* | 4 | 0.01 | 0.02 |
| *Pectocarya recurvata* | 1 | 0.00 | 0.00 |
| *Phacelia ivesiana* | 17 | 0.20 | 0.52 |
| *Stephanomeria exigua* | 8 | 0.17 | 0.49 |
| *Streptanthella longirostris* | 30 | 16.38 | 20.34 |
| Unknown | 1 | 0.00 | 0.00 |

| **TRANSITION (N = 34)** | **Frequency** | **Mean Biomass (g/m^2)** | **Standard Deviation** |
|---|---|---|---|
| *Bromus rubens* | 36 | 8.36 | 12.11 |
| *Bromus tectorum* | 31 | 3.38 | 5.06 |
| *Chorizanthe brevicornu* | 2 | 0.02 | 0.14 |
| *Chorizanthe thurberi* | 7 | 0.03 | 0.07 |
| *Corydalis aurea* | 1 | 0.00 | 0.02 |
| *Cryptantha angustifolia* | 1 | 0.04 | 0.24 |
| *Cryptantha micrantha* | 25 | 0.24 | 1.03 |
| *Cryptantha nevadensis* | 2 | 0.20 | 0.99 |
| *Cryptantha virginensis* | 19 | 0.64 | 1.57 |
| *Cryptantha sp.* | 2 | na | na |
| *Descurainia pinnata* | 35 | 9.11 | 18.21 |
| *Draba cuneifolia* | 6 | 0.02 | 0.10 |
| *Erodium cicutarium* | 31 | 9.80 | 14.47 |
| *Eriastrum diffusum* | 5 | 0.02 | 0.09 |
| *Eriastrum eremicum* | 21 | 0.18 | 0.25 |
| *Eriogonum maculatum* | 3 | 0.02 | 0.12 |
| *Eriogonum nidularium* | 1 | 0.02 | 0.10 |

Appendix X D. (Continued)

| | Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|
| **TRANSITION (continued)** | | | |
| *Eriogonum thomasii* | 1 | 0.01 | 0.08 |
| *Eriophyllum wallacei* | 32 | 0.76 | 1.09 |
| *Festuca octoflora* | 35 | 1.13 | 1.83 |
| *Gilia scopulorum* | 4 | 0.11 | 0.45 |
| *Lepidium flavum* | 3 | 0.04 | 0.19 |
| *Linanthus sp.* | 4 | 0.04 | 0.14 |
| *Microcerus lindleyi* | 9 | 0.12 | 0.37 |
| *Pectocarya recurvata* | 14 | 0.12 | 0.33 |
| *Pectocarya setosa* | 2 | 0.01 | 0.03 |
| *Phacelia bicolor* | 1 | 0.00 | 0.02 |
| *Phacelia ivesiana* | 5 | 0.04 | 0.18 |
| *Plantago insularis* | 16 | 0.20 | 0.46 |
| *Schismus barbatus* | 24 | 1.99 | 6.28 |
| *Silene antirrhinus* | 3 | 0.00 | 0.01 |
| *Stephanomeria exigua* | 8 | 0.23 | 1.12 |
| *Streptanthella longirostris* | 16 | 7.83 | 16.09 |
| *Stylocline micropoides* | 7 | 0.01 | 0.05 |
| Unknown | 1 | 0.00 | 0.00 |
| Unknown grass | 3 | 0.08 | 0.47 |
| Unknown A | 1 | 0.01 | 0.07 |
| | | | |
| **BLACKBRUSH (N = 35)** | | | |
| *Astragalus nuttallii* | 2 | 0.04 | 0.21 |
| *Bromus rubens* | 35 | 4.32 | 9.43 |
| *Bromus tectorum* | 28 | 4.56 | 8.31 |
| *Chorizanthe brevicornu* | 9 | 0.19 | 0.71 |
| *Chorizanthe thurberi* | 9 | 0.04 | 0.16 |
| *Cryptantha angustifolia* | 1 | 0.02 | 0.11 |
| *Cryptantha micrantha* | 7 | 0.02 | 0.09 |
| *Cryptantha nevadensis* | 2 | 0.02 | 0.12 |
| *Cryptantha virginensis* | 13 | 1.26 | 3.73 |
| *Cryptantha sp.* | 7 | 0.14 | 0.57 |
| *Descurainia pinnata* | 11 | 0.44 | 1.82 |
| *Draba cuneifolia* | 12 | 0.04 | 0.09 |
| *Erodium cicutarium* | 34 | 2.23 | 3.50 |
| *Eriastrum diffusum* | 6 | 0.01 | 0.05 |
| *Eriastrum eremicum* | 6 | 0.00 | 0.01 |
| *Eriogonum maculatum* | 2 | 0.02 | 0.08 |
| *Eriogonum nidularium* | 1 | 0.01 | 0.05 |
| *Eriophyllum wallacei* | 6 | 0.03 | 0.13 |
| *Festuca octoflora* | 25 | 0.24 | 0.39 |
| *Gilia leptomeria* | 3 | 0.22 | 0.47 |

Appendix X D. (Continued).

| | Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|
| **BLACKBRUSH (continued)** | | | |
| *Gilia scopulorum* | 16 | 0.00 | 0.00 |
| *Langloisia setosissima* | 1 | 0.01 | 0.05 |
| *Lepidium flavum* | 13 | 0.20 | 0.85 |
| *Linanthus sp.* | 4 | 0.01 | 0.03 |
| *Microcerus lindleyi* | 3 | 0.03 | 0.16 |
| *Pectocarya recurvata* | 19 | 0.40 | 0.86 |
| *Pectocarya setosa* | 2 | 0.01 | 0.03 |
| *Phacelia ivesiana* | 5 | 0.17 | 0.93 |
| *Plantago insularis* | 35 | 0.72 | 0.87 |
| *Schismus barbatus* | 10 | 0.33 | 1.55 |
| *Silene antirrhinus* | 1 | 0.00 | 0.01 |
| *Stephanomeria exigua* | 2 | 0.23 | 1.43 |
| *Streptanthella longirostris* | 1 | 0.01 | 0.09 |
| *Stylocline micropoides* | 2 | 0.00 | 0.01 |
| Unknown | 1 | 0.01 | 0.04 |
| Unknown grass | 4 | 0.02 | 0.08 |
| | | | |
| **ROCKY (N = 15)** | | | |
| *Bromus rubens* | 11 | 4.41 | 15.84 |
| *Bromus tectorum* | 7 | 6.07 | 23.01 |
| *Cryptantha nevadensis* | 1 | 0.61 | 2.53 |
| *Cryptantha virginensis* | 5 | 0.15 | 0.49 |
| *Cryptantha sp.* | | 0.00 | 0.00 |
| *Descurainia pinnata* | 1 | 0.02 | 0.07 |
| *Draba cuneifolia* | 1 | 0.14 | 0.26 |
| *Erodium cicutarium* | 6 | 0.10 | 0.20 |
| *Festuca octoflora* | 4 | 0.04 | 0.16 |
| *Microcerus lindleyi* | 1 | 0.03 | 0.14 |
| *Pectocarya recurvata* | 1 | 0.00 | 0.01 |
| *Phacelia ivesiana* | 3 | 0.02 | 0.07 |
| *Plantago insularis* | 7 | 0.23 | 0.64 |
| *Schismus barbatus* | 1 | 0.00 | 0.01 |
| *Silene antirrhinus* | 2 | 0.01 | 0.01 |
| *Stephanomeria exigua* | 1 | 0.00 | 0.01 |
| Unknown | 1 | 0.00 | 0.01 |
| Unknown grass | 1 | 0.02 | 0.10 |

Appendix X E. Descriptive statistics for spring annual vegetation in four subhabitat types at the Littlefield Site in 1990.

| | Frequency | Relative Frequency | Mean Mass (g/m2) | Standard Deviation |
|---|---|---|---|---|
| **LA* (N=40)** | | | | |
| *Bromus rubens* | 38 | 0.95 | 0.68 | 1.06 |
| *Chorizanthe brevicornu* | 5 | 0.13 | 0.12 | 0.16 |
| *Eriogonum thomasii* | 9 | 0.23 | 0.02 | 0.06 |
| *Erodium cicutarium* | 38 | 0.95 | 1.25 | 0.31 |
| *Lepidium flavum* | 6 | 0.15 | 0.01 | 0.03 |
| *Lesquerella tenella* | 5 | 0.13 | 0.01 | 0.04 |
| *Lotus plebeius* | 1 | 0.03 | ** | 0.00 |
| *Monoptilon bellioides* | 4 | 0.10 | 0.00 | 0.01 |
| *Schismus barbatus* | 39 | 0.97 | 0.46 | 0.65 |
| Unknown Compositae | 3 | 0.08 | 0.00 | 0.00 |
| **LAC* (N=20)** | | | | |
| *Bromus rubens* | 13 | 0.65 | 0.39 | 0.90 |
| *Chorizanthe brevicornu* | 1 | 0.05 | 0.00 | 0.00 |
| *Descurainia pinnata* | 2 | 0.10 | 0.01 | 0.02 |
| *Eriogonum thomasii* | 9 | 0.45 | 0.08 | 0.19 |
| *Erodium cicutarium* | 8 | 0.40 | 0.02 | 0.03 |
| *Lepidium flavum* | 1 | 0.05 | ** | ** |
| *Lesquerella tenella* | 6 | 0.30 | 0.02 | 0.05 |
| *Monoptilon bellioides* | 5 | 0.25 | 0.00 | 0.01 |
| *Pectocarya recurvata* | 1 | 0.05 | 0.00 | 0.01 |
| *Plantago patagonica* | 19 | 0.95 | 0.41 | 0.31 |
| *Schismus barbatus* | 19 | 0.95 | 0.60 | 0.54 |
| **LAH* (N= 25)** | | | | |
| *Bromus rubens* | 22 | 0.88 | 1.00 | 1.34 |
| *Bromus tectorum* | 5 | 0.20 | 0.02 | 0.08 |
| *Eriastrum eremicum* | 7 | 0.28 | 0.02 | 0.04 |
| *Eriogonum thomasii* | 23 | 0.92 | 0.53 | 0.72 |
| *Erodium cicutarium* | 13 | 0.52 | 0.17 | 0.25 |
| *Lepidium flavum* | 2 | 0.08 | 0.00 | 0.01 |
| *Lotus plebeius* | 1 | 0.04 | 0.00 | 0.00 |
| *Monoptilon bellioides* | 1 | 0.04 | 0.02 | 0.04 |
| *Plantago patagonica* | 25 | 1.00 | 0.36 | 0.23 |
| *Schismus barbatus* | 25 | 1.00 | 2.64 | 2.55 |
| Unknown #1 | 1 | 0.04 | 0.00 | 0.00 |

* LA = Larrea-Ambrosia Association
LAC = Larrea-Ambrosia-Ceratoides
LAH = Larrea-Ambrosia-Hilaria
** values <0.01

Appendix X E. (Continued)

| **WASH = (N = 40)** | **Frequency** | **Relative Frequency** | **Mean Mass (g/m2)** | **Standard Deviation** |
|---|---|---|---|---|
| *Bromus rubens* | 35 | 0.88 | 0.19 | 0.20 |
| *Bromus tectorum* | 1 | 0.03 | 0.00 | 0.01 |
| *Chorizanthe brevicornu* | 1 | 0.03 | <0.001 | 0.00 |
| *Descurainia pinnata* | 2 | 0.05 | 0.00 | 0.01 |
| *Eriogonum thomasii* | 4 | 0.10 | 0.00 | 0.00 |
| *Erodium cicutarium* | 19 | 0.48 | 0.11 | 0.20 |
| *Escholtzia minutiflora* | 2 | 0.05 | * | 0.00 |
| *Lepidium flavum* | 2 | 0.05 | 0.00 | 0.01 |
| *Lesquerella tenella* | 1 | 0.03 | 0.00 | 0.01 |
| *Monoptilon bellioides* | 1 | 0.03 | 0.00 | 0.00 |
| *Pectocarya recurvata* | 1 | 0.03 | 0.00 | 0.02 |
| *Plantago patagonica* | 7 | 0.18 | 0.00 | 0.00 |
| *Schismus barbatus* | 21 | 0.53 | 0.09 | 0.16 |

*values that are <0.001

Appendix X F. Descriptive statistics for spring annual vegetation in four subhabitat types at the Littlefield Site in 1991.

| | **Frequency** | **Relative Frequency** | **MeanBiomass (g/m^2)** | **Standard Deviation** |
|---|---|---|---|---|
| **LA (N=40)** | | | | |
| *Astragalus nuttalli* | 2 | 0.05 | 0.06 | 0.27 |
| *Bromus rubens* | 29 | 0.73 | 0.89 | 1.62 |
| *Bromus tectorum* | 1 | 0.03 | 0.00 | 0.01 |
| *Chorizanthe brevicornu* | 1 | 0.03 | 0.00 | 0.00 |
| *Chorizanthe rigida* | 8 | 0.20 | 0.02 | 0.08 |
| *Descurainia pinnata* | 1 | 0.03 | 0.03 | 0.18 |
| *Draba cuneifolia* | 1 | 0.03 | 0.03 | 0.19 |
| *Erodium cicutarium* | 31 | 0.78 | 1.59 | 2.37 |
| *Eriastrum eremicum* | 1 | 0.03 | 0.00 | 0.01 |
| *Erodium texanum* | 4 | 0.10 | 0.17 | 0.82 |
| *Eriogonum thomassii* | 16 | 0.40 | 1.36 | 2.84 |
| *Lepidium flavum* | 12 | 0.30 | 0.32 | 0.65 |
| *Lesquerella tenella* | 4 | 0.10 | 0.17 | 0.70 |
| *Monoptilon bellioides* | 27 | 0.68 | 0.06 | 0.17 |
| *Oenothera primaverus* | 1 | 0.03 | 0.00 | 0.03 |
| *Pectocarya recurvata* | 4 | 0.10 | 0.00 | 0.02 |
| *Plantago insularis* | 4 | 0.10 | 0.14 | 0.44 |
| *Plantago patagonica* | 30 | 0.75 | 0.49 | 1.04 |
| *Schismus barbatus* | 38 | 0.95 | 2.04 | 2.91 |
| Unknown | 1 | 0.03 | 0.00 | 0.00 |
| | | | | |
| **LAC (N = 35)** | | | | |
| *Bromus rubens* | 23 | 0.66 | 0.36 | 0.68 |
| *Bromus tectorum* | 1 | 0.03 | 0.02 | 0.12 |
| *Chorizanthe rigidus* | 3 | 0.09 | 0.00 | 0.01 |
| *erodium cicutarium* | 4 | 0.11 | 0.02 | 0.06 |
| *Eriastrum eremicum* | 1 | 0.03 | 0.00 | 0.01 |
| *Eriogonum thomassi* | 11 | 0.31 | 0.72 | 2.16 |
| *Langloisia setosissima* | 3 | 0.09 | 0.01 | 0.06 |
| *Lepidium flavum* | 4 | 0.11 | 0.07 | 0.27 |
| *Lesquerella tenella* | 14 | 0.40 | 1.03 | 2.04 |
| *Monoptilon bellioides* | 11 | 0.31 | 0.01 | 0.03 |
| *Pectocarya recurvata* | 3 | 0.09 | 0.01 | 0.02 |
| *Phacelia ivesiana* | 5 | 0.14 | 0.06 | 0.27 |
| *Plantago insularis* | 2 | 0.06 | 0.02 | 0.07 |
| *Plantago patagonica* | 29 | 0.83 | 0.65 | 1.09 |
| *Schismus barbatus* | 33 | 0.94 | 1.11 | 1.87 |

Appendix X F. (Continued).

| | Frequency | Relative Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|---|
| **LAH (N = 35 )** | | | | |
| *Bromus rubens* | 26 | 0.74 | 0.79 | 1.37 |
| *Bromus tectorum* | 4 | 0.11 | 0.09 | 0.35 |
| *Erodium cicutarium* | 19 | 0.54 | 0.33 | 0.66 |
| *Eriastrum eremicum* | 11 | 0.31 | 0.20 | 0.51 |
| *Erodium texanum* | 1 | 0.03 | 0.02 | 0.13 |
| *Eriogonum thomasii* | 25 | 0.71 | 4.82 | 6.25 |
| *Monoptilon bellioides* | 9 | 0.26 | 0.01 | 0.02 |
| *Pectocarya recurvata* | 2 | 0.06 | 0.00 | 0.02 |
| *Phacelia ivesiana]* | 2 | 0.06 | 0.00 | 0.02 |
| *Plantago insularis* | 20 | 0.57 | 0.79 | 1.32 |
| *Plantago patagonica* | 30 | 0.86 | 1.04 | 1.21 |
| *Schismus barbatus* | 35 | 1.00 | 2.88 | 4.39 |
| **WASH (N =40)** | | | | |
| *Bromus rubens* | 19 | 0.48 | 0.22 | 0.62 |
| *Erodium cicutarium* | 9 | 0.23 | 0.16 | 0.40 |
| *Lepidium flavum* | 3 | 0.08 | 0.01 | 0.04 |
| *Monoptilon bellioides* | 1 | 0.03 | 0.00 | 0.00 |
| *Pectocarya recurvata* | 1 | 0.03 | 0.00 | 0.00 |
| *Plantago patagonica* | 6 | 0.15 | 0.06 | 0.19 |
| *Schismus barbatus* | 18 | 0.45 | 0.08 | 0.17 |

Appendix X G. Descriptive statistics for spring annual vegetation in four subhabitat types at the Littlefield Site in 1992.

| | Frequency | Relative Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|---|
| **LA (N = 28)** | | | | |
| *Astragalus nuttalli* | 4 | | 0.03 | 0.11 |
| *Bromus rubens* | 29 | | 13.09 | 18.03 |
| *Bromus tectorum* | 6 | | 0.25 | 0.62 |
| *Chorizanthe brevicornu* | 4 | | 0.06 | 0.24 |
| *Chorizanthe rigida* | 3 | | 0.02 | 0.06 |
| *Draba cuneifolia* | 2 | | 0.00 | 0.00 |
| *Erodium cicutarium* | 29 | | 3.62 | 3.87 |
| *Erodium texanum* | 4 | | 0.06 | 0.17 |
| *Eriogonum thomasii* | 15 | | 0.92 | 2.59 |
| *Festuca octaflora* | 5 | | 0.01 | 0.03 |
| *Gilia scopulorum* | 3 | | 0.01 | 0.03 |
| *Langloisia setosissima* | 2 | | 0.00 | 0.01 |
| *Lepidium flavum* | 18 | | 2.37 | 3.67 |
| *Lesquerella tenella* | 5 | | 0.55 | 2.09 |
| *Monoptilon bellioides* | 26 | | 0.23 | 0.30 |
| *Pectocarya recurvata* | 9 | | 0.15 | 0.46 |
| *Plantago insularis* | 2 | | 0.00 | 0.01 |
| *Plantago patagonica* | 22 | | 0.49 | 0.72 |
| *Schismus barbatus* | 30 | | 26.84 | 32.58 |
| *Stylocline micropoides* | 6 | | 0.02 | 0.05 |
| **LAC (N = 36)** | | | | |
| *Bromus rubens* | 34 | | 6.95 | 10.22 |
| *Bromus tectorum* | 9 | | 0.17 | 0.55 |
| *Chorizanthe rigida* | 2 | | 0.03 | 0.17 |
| *Erodium cicutarium* | 12 | | 0.47 | 1.36 |
| *Eriogonum thomasii* | 11 | | 0.24 | 0.93 |
| *Festuca octaflora* | 25 | | 0.24 | 0.51 |
| *Gilia polycladon* | 9 | | 0.02 | 0.07 |
| *Gilia scopulorum* | 1 | | 0.00 | 0.00 |
| *Langloisia setosissima* | 9 | | 0.01 | 0.01 |
| *Lepidium flavum* | 3 | | 1.25 | 6.46 |
| *Lesquerella tenella* | 13 | | 0.98 | 2.44 |
| *Monoptilon bellioides* | 30 | | 0.04 | 0.05 |
| *Pectocarya recurvata* | 5 | | 0.04 | 0.13 |
| *Plantago insularis* | 2 | | 0.00 | 0.00 |
| *Plantago patagonica* | 33 | | 0.95 | 1.38 |
| *Rafinesquia neomexicana* | 2 | | 0.06 | 0.26 |
| *Schismus barbatus* | 35 | | 20.02 | 29.55 |
| *Stephanomeria exigua* | 1 | | 0.08 | 0.47 |

Appendix X G. (Continued)

| | **Frequency** | **Relative Frequency** | **Mean Biomass (g/m^2)** | **Standard Deviation** |
|---|---|---|---|---|
| **LAH (N = 45)** | | | | |
| *Astragalus nuttalli* | 2 | | 0.03 | 0.23 |
| *Bromus rubens* | 44 | | 8.56 | 9.70 |
| *Bromus tectorum* | 21 | | 0.30 | 0.60 |
| *Chorizanthe rigida* | 1 | | 0.00 | 0.01 |
| *Draba cuneifolia* | 1 | | 0.00 | 0.01 |
| *Erodium cicutarium* | 26 | | 0.89 | 1.48 |
| *Eriastrum diffusum* | 2 | | 0.01 | 0.03 |
| *Eriastrum eremicum* | 4 | | 0.01 | 0.05 |
| *Erodium texanum* | 3 | | 0.01 | 0.04 |
| *Eriogonum thomasii* | 35 | | 7.07 | 11.93 |
| *Festuca octoflora* | 35 | | 0.59 | 1.00 |
| *Gilia polycladon* | 4 | | 0.00 | 0.02 |
| *Langloisia setosissima* | 3 | | 0.00 | 0.02 |
| *Lepidium flavum* | 4 | | 0.19 | 0.93 |
| *Lesquerella tenella* | 3 | | 0.04 | 0.23 |
| *Monoptilon bellioides* | 25 | | 0.04 | 0.08 |
| *Pectocarya recurvata* | 9 | | 0.14 | 0.61 |
| *Plantago insularis* | 22 | | 0.32 | 0.55 |
| *Plantago patagonica* | 41 | | 1.72 | 2.84 |
| *Rafinesquia neomexicana* | 6 | | 0.30 | 1.21 |
| *Schismus barbatus* | 44 | | 18.38 | 18.10 |
| *Streptanthella longirostris* | 3 | | 0.32 | 1.51 |
| | | | | |
| **WASH (N = 39)** | | | | |
| -none- | 1 | | | |
| *Bromus rubens* | 38 | | 3.36 | 5.56 |
| *Bromus tectorum* | 14 | | 0.70 | 2.19 |
| *Chorizanthe brevicornu* | 1 | | na * | na |
| *Descurainia pinnata* | 7 | | 0.06 | 0.26 |
| *Draba cuneifolia* | 3 | | 0.09 | 0.56 |
| *Erodium cicutarium* | 28 | | 0.28 | 0.51 |
| *Eriastrum diffusum* | 1 | | na | na |
| *Eriogonum thomasii* | 11 | | 0.01 | 0.07 |
| *Gilia scopulorum* | 1 | | 0.00 | 0.00 |
| *Hordeum murinum* | 2 | | 0.00 | 0.03 |
| *Langloisia setosissima* | 2 | | na | na |
| *Lepidium flavum* | 23 | | 0.11 | 0.35 |
| *Lesquerella tenella* | 4 | | 0.05 | 0.33 |
| *Linanthus dichotomus* | 1 | | 0.00 | 0.00 |
| *Monoptilon bellioides* | 6 | | 0.00 | 0.00 |
| *Pectocarya recurvata* | 6 | | 0.01 | 0.04 |
| *Plantago insularis* | 4 | | na | na |

** no data available*

Appendix X G. (Continued).

| | Frequency | Relative Frequency | Mean Biomass (g/m^2) | Standard Deviation |
|---|---|---|---|---|
| **WASH (Continued)** | | | | |
| *Plantago patagonica* | 16 | | 0.06 | 0.18 |
| *Salsola iberica* | 1 | | na * | na |
| *Schismus barbatus* | 37 | | 2.48 | 4.02 |
| *Streptanthella longirostris* | 1 | | na | na |
| *Stylocline micropoides* | 1 | | 0.00 | 0.00 |

* no data available

Appendix XI. Descriptive statistics and statistical analysis of perennial plant cover among subhabitat types (1990) at the City Creek Site, and the Littlefield Site.

Appendix XI A. Descriptive statistics and statistical analysis testing for significant differences of perennial plant cover among for subhabitat types at the City Creek Site in 1990.

| **Subhabitat** | **Mean Cover *** | **Standard Deviation** | **Number of Transects** |
|---|---|---|---|
| Dune | 1071.2 | 332.1 | 10 |
| Rocky | 535.5 | 249.0 | 8 |
| Blackbrush | 765.9 | 351.6 | 11 |
| Transition | 913.5 | 412.8 | 10 |

**Type III sums of squares, analysis of variance**
DF = 38; F-statistic = 3.863; P-value = .0173

**Post-hoc test of significance using Fisher's LSD.**

| *Subhabitat Comparison *** | *F-statistic* | *P-value* |
|---|---|---|
| R - B | 230.4 | 0.1610 |
| R - T | 378.0 | 0.0274 |
| R - D | 535.7 | 0.0025 |
| B - T | 147.6 | 0.3360 |
| B - D | 305.3 | 0.0513 |
| T - D | 157.7 | 0.3155 |

* cover measured in cm per 5000 cm line transect

** (D) Dune; (R) Rocky; (B) Blackbrush; (T) Transition

Appendix XI B. Descriptive statistics and statistical analysis testing for significant differences of perennial plant cover among for subhabitat types at the Littlefield Site in 1990.

| **Subhabitat** * | **Mean Cover** ** | **Standard Deviation** | **Number of Transects** |
|---|---|---|---|
| LA | 810.0 | 319.2 | 12 |
| LAH | 909.2 | 296.5 | 11 |
| LAC | 1060.2 | 399.7 | 10 |
| Wash | 1434.7 | 579.0 | 15 |

**Type III sums of squares, analysis of variance**
DF = 47; F-statistic = 5.569; P-value = .0025

**Post-hoc test of significance using Fisher's LSD.**

| *Subhabitat Comparison* ** | *F-statistic* | *P-value* |
|---|---|---|
| LA - LAH | 99.2 | 0.5832 |
| LA - LAC | 250.2 | 0.1810 |
| LA - Wash | 624.7 | 0.0005 |
| LAH - LAC | 151.0 | 0.4257 |
| LAH - Wash | 525.6 | 0.0036 |
| LAC - Wash | 374.5 | 0.0384 |

| | |
|---|---|
| * LA | Larrea tridentata-Ambrosia dumosa |
| LAH | L. tridentata-A. dumosa-Hilaria rigida |
| LAC | L. tridentata-A. dumosa-Ceratoides lanata |
| Wash | margins of arroyos and washes |

** cover measured in cm per 5000 cm line transect

## Appendix XII. Descriptive statistics for perennial vegetation by species (1990) at the City Creek Site and, the Littlefield Site.

Appendix XII A. Descriptive statistics for perennial vegetation by species at the City Creek Site. Spring 1990.

| | **DUNE** | | **ROCKY** | | **BLACKBRUSH** | | **TRANSITION** | |
|---|---|---|---|---|---|---|---|---|
| SPECIES | Estimated Mean Cover† | SD | Estimated Mean Cover† | SD | Estimated Mean Cover† | SD | Estimated Mean Cover† | SD |
| *Artemesia filifolia* | 292.7 | 167.8 | * | * | * | * | * | * |
| *Baileya multiradiata* | * | * | * | * | * | * | 3.7 | 11.7 |
| *Coleogyne ramisissima* | 29.2 | 92.3 | 303.0 | 227.4 | 383.7 | 224.7 | 163.4 | 196.9 |
| *Croton californica* | 2.8 | 5.9 | * | * | * | * | * | * |
| *Encelia frutescens* | * | * | 6.6 | 18.7 | 10.7 | 35.6 | 5.6 | 17.7 |
| *Ephedra nevadensis* | 498.9 | 345.3 | 102.5 | 123.4 | 216.5 | 230.4 | 383.2 | 421.8 |
| *Eriogonum fasciculatum* | 5.7 | 18.0 | 73.8 | 88.2 | 31.9 | 56.9 | 34.4 | 108.8 |
| *Gutieurezzia sp.* | 16.1 | 28.7 | 20.0 | 35.3 | 18.2 | 19.4 | 106.0 | 142.8 |
| *Heterotheca villosa* | * | * | 5.8 | 11.0 | * | * | * | * |
| *Hymenoclea salsola* | 7.1 | 22.5 | * | * | 23.1 | 60.6 | 86.1 | 121.2 |
| *Krameria parvifolia* | * | * | 57.6 | 85.0 | 59.6 | 64.1 | 77.4 | 109.3 |
| *Larrea tridentata* | 75.0 | 237.2 | * | * | 22.1 | 73.3 | 17.3 | 50.6 |
| *Lomatium scabra,* | * | * | 0.8 | 2.1 | * | * | * | * |
| *Lotus plebieus* | * | * | 5.4 | 15.2 | * | * | * | * |
| *Opuntia erinaceae* | * | * | * | * | 2.0 | 4.7 | * | * |
| *Stipa hymenoides* | 6.3 | 14.9 | 8.9 | 25.1 | * | * | * | * |
| *Prunus fasciculatum* | 131.7 | 165.1 | * | * | * | * | 29.3 | 50.3 |
| *Rumex hymenosepalus* | * | * | * | * | * | * | 1.1 | 3.5 |
| *Stephanomeria exigua* | * | * | * | * | * | * | 0.2 | 0.6 |
| *Stephanomeria pauciflora* | 5.7 | 13.0 | * | * | * | * | * | * |
| **Total Mean Cover** | 1071 | | 584.3 | | 767.7 | | 907.7 | |

† Calculated as the mean number of cm cover per 50m line-intercept transect, per species

* no data

Appendix XII B. Descriptive statistics for perennial vegetation by species at the Littlefield Site. Spring 1990.

| SPECIES | *LA* Estimated Mean Cover† | SD | *LAC* Estimated Mean Cover† | SD | *LAH* Estimated Mean Cover† | SD | **Wash** Estimated Mean Cover† | SD |
|---|---|---|---|---|---|---|---|---|
| *Ambrosia dumosa* | 279.0 | 174.8 | 355.0 | 189.2 | 343.2 | 174.9 | 306.1 | 264.5 |
| *Atriplex canescens* | * | * | * | * | * | * | 17.4 | 67.4 |
| *Aristida purpurea* | 2.8 | 9.5 | * | * | * | * | * | * |
| *Baccharis sergiloides* | * | * | * | * | * | * | 326.9 | 372.0 |
| *Ceratoides lanata* | * | * | 73.2 | 168.3 | * | * | 4.4 | 13.7 |
| *Erioneuron pulchellum* | 2.5 | 3.9 | * | * | * | * | * | * |
| *Hilaria rigida* | * | * | 0.8 | 2.7 | 27.1 | 58.3 | 1.9 | 7.2 |
| *Hymenoclea salsola* | * | * | * | * | * | * | 307.1 | 321.4 |
| *Krameria greyi* | * | * | 8.3 | 18.4 | * | * | 57.2 | 101.0 |
| *Larrea tridentata* | 222.9 | 193.4 | 304.8 | 307.7 | 519.7 | 213.5 | 324.9 | 276.8 |
| *Lycium species* | * | * | * | * | 19.0 | 48.1 | 86.3 | 127.4 |
| *Stipa hymenoides* | * | * | * | * | 0.2 | 0.6 | * | * |
| *Senecio douglassii* | * | * | * | * | * | * | 0.8 | 3.1 |
| *Stephanomeria pauciflora* | * | * | * | * | * | * | 1.6 | 6.2 |
| **Total Mean Cover** | **507.2** | | **742.1** | | **909.2** | | **1435** | |

† Calculated as the mean number of cm per 50m line-intercept transect, per species.

* no data

** LA = Larrea-Ambrosia; LAC = Larrea-Ambrosia-Ceratoides; LAH = Larrea-Ambrosia-Hilaria.

Appendix XIII. Aboveground biomass production estimates for desert annual plants at nine sites on the upper bajada of Utah Hill and the Beaver Dam Slope of southwest Utah, in April and May of 1980 - 1991.

Appendix XIII. Aboveground biomass production * for desert annual plants, at nine sites, on the upper bajada of Utah Hill and the Beaver Dam Mountains of southwest Utah, 1980 - 1991.

| | | *APRIL* | | *MAY* | |
|---|---|---|---|---|---|
| **Year** | **Sample Site†** | **(kg/ha)** | **Means** | **(kg/ha)** | **Means** |
| 1980 | 1 | 212.4 | | 403.5 | |
| 1980 | 5 | 282.6 | | 211.5 | |
| 1980 | 8 | 197.3 | 230.8 | 168 | 261.0 |
| 1981 | 2 | 55.1 | | 165.3 | |
| 1981 | 4 | 27.6 | | 72.9 | |
| 1981 | 9 | 23.1 | 35.3 | 35.6 | 91.3 |
| 1982 | 3 | 34.7 | | 94.2 | |
| 1982 | 6 | 1.8 | | 22.2 | |
| 1982 | 7 | 8.9 | 15.1 | 33.8 | 50.1 |
| 1983 | 1 | 535.9 | | 555.5 | |
| 1983 | 5 | 217.8 | | 609.7 | |
| 1983 | 8 | 822.1 | 525.3 | 475.5 | 546.9 |
| 1984 | 2 | 23.1 | | 141.3 | |
| 1984 | 4 | 68.4 | | 80.9 | |
| 1984 | 9 | 76.4 | 56.0 | 66.7 | 96.3 |
| 1985 | 3 | 61.3 | | 43.6 | |
| 1985 | 6 | 37.3 | | 13.3 | |
| 1985 | 7 | 82.7 | 60.4 | 26.7 | 27.9 |
| 1986 | 1 | 313.7 | | 172.4 | |
| 1986 | 5 | 72.9 | | 93.3 | |
| 1986 | 8 | 126.2 | 170.9 | 148.4 | 138.0 |
| 1987 | 2 | 160.9 | | 104.9 | |
| 1987 | 4 | 181.3 | | 132.4 | |
| 1987 | 9 | 72.9 | 138.4 | 40 | 92.4 |
| 1988 | 3 | 221.3 | | 181.3 | |
| 1988 | 6 | 128.9 | | 10.7 | |
| 1988 | 7 | 157.3 | 169.2 | 125.3 | 105.8 |
| 1989** | - | 0 | | 0 | |
| 1989** | - | 0 | | 0 | |
| 1989** | - | 0 | 0.0 | 0 | 0.0 |
| 1990 | 2 | 33.8 | | - | |
| 1990 | 4 | 24 | | - | |
| 1990 | 9 | 17.8 | 25.2 | - | |
| 1991 | 1 | 497.7 | | - | |

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* Biomass estimates reported are dry weights.

** Biomass production was so little it was not measurable.

† Nine sites that are sampled systematically.

Appendix XIII. (Continued)

|  |  | *APRIL* |  | *MAY* |  |
|---|---|---|---|---|---|
| **Year** | **Sample Site†** | **(kg/ha)** | **Means** | **(kg/ha)** | **Means** |
| 1991 | 5 | 55.1 |  | - |  |
| 1991 | 8 | 268.4 | 273.7 | - |  |
| 1992 | 3 | 278.1 |  | 544.8 |  |
| 1992 | 6 | 256.7 |  | 226.4 |  |
| 1992 | 7 | 524.1 | 353.0 | 184.9 | 318.7 |
| 1993 | 2 | *** |  | 475.3 |  |
| 1993 | 4 | *** |  | 383.0 |  |
| 1993 | 9 | *** | *** | 214.6 | 357.6 |
|  | **Average** | **157.94** | **157.94** | **173.83** | **173.83** |
|  | **Variance** | **32815.25** | **24188.97** | **30648.72** | **26705.22** |

* Biomass estimates reported are dry weights.

** Biomass production was so little it was not measurable.

*** no data were collected

† Nine sites that are sampled systematically.

Appendix XIV. List of plant species eaten by tortoises and arranged by number of bites at the City Creek Site in 1989 - 1992 (A - D) and, the Littlefield Site in 1990 - 1992 (E - G).

Appendix XIV A. List of plant species eaten by tortoises at the City Creek Site. 14 April to June 1989. Number of tortoises found was fourteen (10 F*, 4 unk.).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Bromus rubens* | 6245 | 53.79 |
| *Erodium cicutarium* | 2687 | 23.14 |
| *Bromus tectorum* | 945 | 8.14 |
| *Krameria parvifolia* | 488 | 4.20 |
| *Hilaria rigida* | 327 | 2.82 |
| *Cryptantha micrantha* | 182 | 1.57 |
| *Stipa hymenoides* | 143 | 1.23 |
| *Euphorbia parryi* | 119 | 1.02 |
| *Oenothera pallida* | 92 | 0.79 |
| *Helianthus anomalus* | 86 | 0.74 |
| *Opuntia erinacea* | 57 | 0.49 |
| *Stephanomeria paucifolia* | 53 | 0.46 |
| *Aristida purpurea* | 46 | 0.40 |
| *Ephedra nevadensis* | 33 | 0.28 |
| *Langloisia schottii* | 33 | 0.28 |
| *Tridens muticus* | 33 | 0.28 |
| *Eriophyllum wallacei* | 12 | 0.10 |
| *Coleogyne ramosissma* | 8 | 0.07 |
| *Plantago patagonica* | 7 | 0.06 |
| *Gutierezzia sp.* | 6 | 0.05 |
| *Hymenoxes filifolia* | 5 | 0.04 |
| *Heterotheca villosa* | 2 | 0.02 |
| *Cryptantha nevadensis* | 1 | 0.01 |
| *Encelia frutescens* | ** | ** |
| **TOTAL** | 11610 | 100 |
| ***Other materials in diets*** | | |
| Unknown species | 44 | 0.37 |

* M = male; F = female; unk. = unknown

** trace amount

Appendix XIV B. List of plant species eaten by tortoises at the City Creek Site.
19 April to 27 June,1990. Number of tortoises found
was eight (all F).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Bromus rubens* | 12069 | 39.96 |
| *Schismus barbatus* | 8114 | 26.86 |
| *Erodium cicutarium* | 2920 | 9.67 |
| *Cryptantha micrantha* | 1022 | 3.38 |
| *Bromus tectorum* | 1020 | 3.38 |
| *Stipa hymenoides* | 744 | 2.46 |
| *Stephanomeria exigua* | 602 | 1.99 |
| *Gaura coccinus* | 506 | 1.68 |
| *Streptanthella longirostris* | 375 | 1.24 |
| *Aristida purpurea* | 339 | 1.12 |
| *Coleogyne ramosissima* | 312 | 1.03 |
| *Eriophyllum wallacii* | 297 | 0.98 |
| *Phacelia ivesiana* | 260 | 0.86 |
| *Abronia fragrans* | 245 | 0.81 |
| *Cryptantha virginensis* | 238 | 0.79 |
| *Krameria parvifolia* | 155 | 0.51 |
| *Gilia leptomeria* | 89 | 0.29 |
| *Cryptantha angustifolia* | 87 | 0.29 |
| *Pectocarya recurvata* | 81 | 0.27 |
| *Chorizanthe thurberi* | 131 | 0.43 |
| *Salsola iberica* | 57 | 0.19 |
| *Descurainia pinnata* | 56 | 0.19 |
| *Unknown grass* | 56 | 0.19 |
| *Euphorbia parryi* | 52 | 0.17 |
| *Echinocereus englemannii* | 49 | 0.16 |
| *Eriastrum eremicum* | 47 | 0.16 |
| *Cryptantha sp.* | 43 | 0.14 |
| *Eriogonum fasciculatum* | 31 | 0.10 |
| *Oenothera pallida* | 26 | 0.09 |
| *Cryptantha nevadensis* | 25 | 0.08 |
| *Helianthus anomalus* | 22 | 0.07 |
| *Gutierrezia spp.* | 21 | 0.07 |
| *Opuntia sp.* | 21 | 0.07 |
| *Eriogonum inflatum* | 19 | 0.06 |
| *Ephedra nevadensis* | 17 | 0.06 |
| *Plantago patagonica* | 17 | 0.06 |
| *Eriogonum maculatum* | 12 | 0.04 |
| *Thysanocarpus curvipes* | 9 | 0.03 |
| *Heterotheca villosa* | 6 | 0.02 |
| *Yucca utahensis* | 4 | 0.01 |
| *Dithyrea wislizenii* | 3 | 0.00 |

Appendix XIV B. (Continued)

| Species | Total Number of Bites | Percent of Bites |
|---|---|---|
| *Eriogonum thomasii* | 3 | 0.00 |
| *Androstephium breviflora* | 2 | 0.00 |
| **TOTAL** | **30205** | |
| ***Other materials in diets*** | | |
| Litter | 534 | |
| Unknown species | 277 | |
| Scat | 248 | |
| Rock | 38 | |

Appendix XIV C. List of plant species eaten by tortoises at the City Creek Site. April 9 to September 9, 1991. Number of tortoises fond was thirteen (M = 6; F = 7).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Erodium cicutarium* | 6307 | 16.32 |
| *Descurainia pinnata* | 4882 | 12.63 |
| *Bromus rubens* | 3073 | 7.95 |
| *Bromus tectorum* | 2401 | 6.21 |
| *Oenothera deltoides* | 2136 | 5.53 |
| *Androstephium breviflorum* | 2005 | 5.19 |
| *Cryptantha nevadensis* | 1704 | 4.41 |
| *Dithyrea wislizenii* | 1592 | 4.12 |
| *Schismus barbatus* | 1488 | 3.85 |
| *Gilia leptomeria* | 1436 | 3.72 |
| *Lepidium flavum* | 1319 | 3.41 |
| *Cryptantha micrantha* | 1251 | 3.24 |
| *Hilaria rigida* | 1029 | 2.66 |
| *Stephanomeria exigua* | 997 | 2.58 |
| *Krameria parvifolia* | 807 | 2.09 |
| *Eriophyllum wallacei* | 601 | 1.55 |
| *Gilia scopulorum* | 589 | 1.52 |
| *Descurainia and Litter* | 580 | 1.50 |
| *Stipa hymenoides* | 500 | 1.29 |
| *Plantago patagonica* | 471 | 1.22 |
| *Pectocarya recurvata* | 318 | 0.82 |
| *Echinocereus englemannii* | 290 | 0.75 |
| *Streptanthella longirostris* | 218 | 0.56 |
| *Plantago insularis* | 201 | 0.52 |
| *Phacelia ivesiana* | 190 | 0.49 |
| *Draba cuneifolia* | 188 | 0.49 |
| *Calochortus nuttallii* | 187 | 0.48 |
| *Phacelia bicolor* | 185 | 0.48 |
| *Astragalus sp.* | 157 | 0.41 |
| *Lepidium flavum and Bromus rubens* | 145 | 0.38 |
| *Dichellostoma pulchellum* | 140 | 0.36 |
| *Chorizanthe thurberi* | 104 | 0.27 |
| *Opuntia erinacea* | 100 | 0.26 |
| *Phacelia crenulata* | 97 | 0.25 |
| *Gaura coccinnia* | 93 | 0.24 |
| *Linanthus sp.* | 82 | 0.21 |
| *Baileya multiradiata* | 75 | 0.19 |
| *Abronia fragrans* | 73 | 0.19 |
| *Oenothera primaverus* | 66 | 0.17 |
| *Stylocline micropoides* | 64 | 0.17 |
| *Bromus sp.* | 58 | 0.15 |

Continued Appendix XIV C.

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Eriastrum eremicum* | 54 | 0.14 |
| *Aristida purpurea* | 45 | 0.12 |
| *Plantago sp.* | 44 | 0.11 |
| *Bromus tectorum and Hilaria rigida* | 41 | 0.11 |
| *Spharalcea sp.* | 39 | 0.10 |
| *Lotus plebeius* | 36 | 0.09 |
| *Androstephium and Bromus rubens* | 35 | 0.09 |
| *Ephedra nevadensis* | 28 | 0.07 |
| *Hymenoclea salsola* | 18 | 0.05 |
| *Salsola iberica* | 18 | 0.05 |
| *Bromus rubens and litter* | 16 | 0.04 |
| *Baileya pleniradiata* | 14 | 0.04 |
| *Baileya sp.* | 13 | 0.03 |
| *Gilia sp.* | 12 | 0.03 |
| *Chorizanthe brevicornu* | 10 | 0.03 |
| *Silene antirhinna* | 7 | 0.02 |
| *Camissonia andina* | 6 | 0.02 |
| *Eriogonum fasciculatum* | 6 | 0.02 |
| *Gutierrezia sp.* | 3 | 0.01 |
| *Coleogyne ramosissima* | 1 | 0.00 |
| **SUM TOTAL** | 38645 | 99.98 |
| ***Other materials in diets*** | | |
| Litter | 497 | |
| Unknown species | 436 | |
| Tortoise Feces | 141 | |
| Rabbit Feces | 29 | |
| Bone | 28 | |
| Soil | 23 | |
| Caliche Rock | 10 | |

Appendix XIV D. List of plants eaten by tortoises at the City Creek Site. April 18 to August 6, 1992. Number of tortoises was twenty-two (M = 7; F = 14; unknown sex 1).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Erodium cicutarium* | 9041 | 24.09 |
| *Stephanomeria exigua* | 5290 | 14.10 |
| *Stipa hymenoides** | 2216 | 5.90 |
| *Lotus plebeius*** | 3496 | 9.32 |
| *Cryptantha micrantha* | 2048 | 5.46 |
| *Schismus barbatus* | 1544 | 4.11 |
| *Bromus rubens* | 1407 | 3.75 |
| *Festuca octoflora* | 1234 | 3.29 |
| *Euphorbia parryi* | 1210 | 3.22 |
| *Cryptantha nevadensis* | 787 | 2.10 |
| *Lupinus coccinea* | 746 | 1.99 |
| *Hiliaria rigida* | 727 | 1.94 |
| *Bromus tectorum* | 711 | 1.89 |
| *Calochortus nuttallii* | 588 | 1.57 |
| *Lepidium flavum* | 538 | 1.43 |
| *Dichelostemma pulchellum* | 529 | 1.41 |
| *Gilia leptomeria* | 491 | 1.31 |
| *Streptanthella longirostris* | 440 | 1.17 |
| *Eriophyllum wallacei* | 387 | 1.03 |
| *Amsinkia tessellata* | 385 | 1.03 |
| *Abronia fragrans* | 380 | 1.01 |
| *Cryptantha virginensis* | 355 | 0.95 |
| *Cryptantha sp.* | 328 | 0.87 |
| *Descurainia pinnata* | 285 | 0.76 |
| *Delphinium nuttallianum* | 275 | 0.73 |
| *Plantago insularis* | 243 | 0.65 |
| *Gilia scopulorum* | 251 | 0.67 |
| *Androstephium brevifolium* | 181 | 0.48 |
| *Eriastrum eremicum* | 107 | 0.29 |
| *Astragalus nuttallii* | 104 | 0.28 |
| *Coleogyne ramosissima* | 99 | 0.26 |
| *Camissonia Boothii**** | 83 | 0.22 |
| *Monoptilon bellioides* | 78 | 0.21 |
| *Phacelia ivesiana* | 76 | 0.20 |
| *Plantago patagonica* | 76 | 0.20 |
| *Euphorbia micromera* | 70 | 0.19 |
| *Sphaeralcea ambigua* | 70 | 0.19 |
| *Sporobolus flexuosus* | 70 | 0.19 |
| *Aristida purpurea* | 59 | 0.16 |
| *Ephedra nevadensis* | 59 | 0.16 |
| *Linanthus dichotomos* | 57 | 0.15 |
| *Chorizanthe thurberi* | 56 | 0.15 |

Appendix XIV D. (Continued)

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Elymus elymoides***** | 44 | 0.12 |
| *Helianthus anomalus* | 39 | 0.10 |
| *Draba cuneifolia* | 38 | 0.10 |
| *Phacelia bicolor* | 35 | 0.09 |
| *Chorizanthe brevicornu* | 33 | 0.09 |
| *Camissonia brevipes* | 28 | 0.07 |
| *Pectocarya recurvata* | 27 | 0.07 |
| *Croton californicus* | 21 | 0.06 |
| *Krmaeria parvifolium* | 20 | 0.05 |
| *Eriogonum maculatum* | 18 | 0.05 |
| *Stylocline micropoides* | 14 | 0.04 |
| *Eriastrum diffusum* | 12 | 0.03 |
| *Salsola iberica* | 11 | 0.03 |
| *Bromus sp.* | 7 | 0.02 |
| Rabbit pellet | 3 | 0.01 |
| **Total** | **37529** | 100.00 |
| ***Other materials in diets*** | | |
| Unknown | 452 | |
| Tortoise Scat | 160 | |
| Litter | 10 | |
| Soil | 10 | |

* Formerly Oryzopsis hymenoides
** Formerly known as L. rigidus in reports and communications.
*** formerly Oenothera decorticans
**** Formerly Sitanion hystrix

Appendix XIV E. List of tortoises eaten by tortoises at the Littlefield Site.
May 4 to June 14, 1990. Number of tortoises was
eight (all female).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Schismus barbatus* | 3133 | 45.16 |
| *Erodium cicutarium* | 1484 | 21.39 |
| *Bromus rubens* | 828 | 11.94 |
| *Opuntia basilaris* | 567 | 8.17 |
| *Erioneuron pulchellum* | 311 | 4.48 |
| *Plantago patagonica* | 224 | 3.23 |
| *Hilaria rigida* | 216 | 3.11 |
| *Stipa hymenoides* | 112 | 1.61 |
| *Krameria parvifolia* | 23 | 0.33 |
| *Mirabilis sp.* | 20 | 0.29 |
| *Eriogonum thomasii* | 8 | 0.12 |
| *Plantago insularis* | 7 | 0.10 |
| *Ceratoides lanata* | 4 | 0.06 |
| **TOTAL** | 6937 | 100.00 |
| ***Other materials in diets*** | | |
| Feces | 7 | |
| Rock | 17 | |
| Unknown species | 107 | |

Appendix XIV F. List of plants eaten by tortoises at the Littlefield Site.
April 8 to September 10, 1991. Number of tortoises was
twelve (F = 6; M = 6).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Plantago spp.* | 6185 | 36.69 |
| *Schismus barbatus* | 3929 | 23.31 |
| *Erodium spp.* | 2461 | 14.60 |
| *Lepidium flavum* | 1110 | 6.59 |
| *Eriogonum Thomassii* | 738 | 4.38 |
| *Lesquerella tennella* | 727 | 4.31 |
| *Monoptilon bellioides* | 383 | 2.27 |
| *Oenethera premaverus* | 306 | 1.82 |
| *Bromus spp.* | 276 | 1.64 |
| *Erioneuron pulchellum* | 262 | 1.55 |
| *Stipa hymenoides* | 221 | 1.31 |
| *Pectocarya recurvata* | 80 | 0.47 |
| *Phacelia ivesianna* | 55 | 0.33 |
| *Langloissia setossissima* | 50 | 0.30 |
| *Hilaria rigida* | 31 | 0.18 |
| *Rafinesquia neomexicana* | 15 | 0.09 |
| *Chorizanthe rigida* | 13 | 0.08 |
| *Gilia spp.* | 6 | 0.04 |
| *Ephedra nevadensis* | 3 | 0.02 |
| *Krameria parvifolia* | 3 | 0.02 |
| *Strepthanthella longirostris* | 2 | 0.01 |
| **TOTAL** | 16856 | 100.00 |
| ***Other materials in diets*** | | |
| Unknown species | 49 | |
| Litter | 17 | |
| Unknown Feces | 6 | |

Appendix XIV G. List of plants eaten by tortoises at the Littlefield Site.
April 13 to 18,1992. Number of tortoises was
seventeen (M = 9; F = 7; unknown sex = 1).

| **Species** | **Total Number of Bites** | **Percent of Bites** |
|---|---|---|
| *Schismus barbatus* | 4065 | 41.52 |
| *Erodium cicutarium* | 2081 | 21.25 |
| *Plantago patagonica* | 1174 | 11.99 |
| *Festuca octoflora* | 673 | 6.87 |
| *Sphaeralcea ambigua* | 367 | 3.75 |
| *Stephanomeria exigua* | 301 | 3.07 |
| *Lepidium flavum* | 274 | 2.80 |
| *Bromus rubens* | 148 | 1.51 |
| *Cryptantha micrantha* | 144 | 1.47 |
| *Glyptopleura setulosa* | 117 | 1.19 |
| *Pectocarya recurvata* | 100 | 1.02 |
| *Mirabilis multiflora* | 96 | 0.98 |
| *Eriogonum thomassii* | 73 | 0.75 |
| *Cryptantha nevadensis* | 49 | 0.50 |
| *Lesquerella tenella* | 44 | 0.45 |
| *Lotus plebeius* | 34 | 0.35 |
| *Stipa hymenoides* | 20 | 0.20 |
| *Ambrosia dumosa* | 10 | 0.10 |
| *Erioneuron pulchellum* | 8 | 0.08 |
| *Euphorbia parryi* | 5 | 0.05 |
| *Cryptantha sp.* | 4 | 0.04 |
| *Plantago insularis* | 4 | 0.04 |
| **Total** | 9791 | 100.00 |

| ***Other materials in diets*** | |
|---|---|
| Unknown | 65 |
| Rabbit Pellet | 94 |

Appendix XV. Alphabetical lists of all diet plants at the City Creek Site (A) and, the Littlefield Site (B) in 1989 - 1992.

Appendix XV A. Alphabetical list of all diet plants at the City Creek Site. 1989 - 1992.

| Latin Name | Common Name |
|---|---|
| *Abronia fragrans* | fragrant sand verbena |
| *Amsinckia tessellata* | rough fiddleneck |
| *Androstephium breviflorum* | |
| *Aristida purpurea* | purple three-awn |
| *Astragalus nuttallii* | Nuttall's astragalus |
| *Baileya multiradiata* | desert marigold |
| *Baileya pleniradiata* | woolly marigold |
| *Bouteloua aristidoides* | |
| *Bromus rubens* | red brome |
| *Bromus tectorum* | cheat grass |
| *Calochortus nuttallii* | sego lily |
| *Camissonia andina* | |
| *Camissonia Boothii* | bottle brush |
| *Camissonia brevipes* | yellow cups |
| *Chorizanthe brevicornu* | short spine-flower |
| *Chorizanthe thurberi* | Thurber spine-flower |
| *Coleogyne ramosissima* | blackbrush |
| *Croton californicus* | Mohave croton |
| *Cryptantha angustifolia* | narrowleaf cryptanth |
| *Cryptantha micrantha* | dye cryptanth |
| *Cryptantha nevadensis* | Nevada cryptanth |
| *Cryptantha virginensis* | Virgin cryptanth |
| *Delphinium nuttallianum* | Nelson larkspur |
| *Descurainia pinnata* | pinnate tansy-mustard |
| *Dichelostemma pulchellum* | blue dick |
| *Dithyrea wislizenii* | spectacle-pod |
| *Draba cuneifolia* | wedgeleaf |
| *Echinocereus englemannii* | Englemann hedgehog cactus |
| *Elymus elymoides* | squirreltail grass |
| *Encelia frutescens* | bush encelia |
| *Ephedra nevadensis* | Nevada ephedra |
| *Eriastrum diffusum* | |
| *Eriastrum eremicum* | desert gilia |
| *Eriogonum fasciculatum* | Mojave buckwheat |
| *Eriogonum inflatum* | desert trumpet |
| *Eriogonum maculatum* | red-spotted buckwheat |
| *Eriogonum thomasii* | Thomas buckwheat |
| *Eriophyllum wallacei* | woolly daisy |
| *Erodium cicutarium* | filaree |
| *Euphorbia micromera* | sand mat |
| *Euphorbia parryi* | Parry spurge |
| *Festuca octoflora* | six weeks fescue |
| *Gaura coccinnia* | scarlet gaura |
| *Gilia leptomeria* | tooth-leaved gilia |
| *Gilia scopulorum* | rock gilia |
| *Gutierrezia sp.* | snakeweed |
| *Helianthus anomalus* | sand sunflower |

Appendix XV A. (Continued).

| | |
|---|---|
| *Heterotheca villosa* | hairy goldenaster |
| *Hilaria rigida* | big galleta |
| *Hymenoclea salsola* | burrobush |
| *Hymenopappus filifolius* | yellow cutleaf |
| *Krameria parvifolia* | range ratany |
| *Langloisia setosissima* | bristly gilia |
| *Lepidium flavum* | yellow pepper-grass |
| *Linanthus dichotomous* | |
| *Lotus plebeius* | long-bracted trefoil |
| *Lupinus coccinea* | lupine |
| *Monoptilon bellioides* | Mojave desert star |
| *Oenothera deltoides* | annual evening primrose |
| *Oenothera pallida* | pale evening primrose |
| *Oenothera primiveris* | evening primrose |
| *Opuntia erinacea* | prickly pear |
| *Pectocarya recurvata* | bent combseed |
| *Phacelia bicolor* | two-colored phacelia |
| *Phacelia crenulata* | notch-leaved phacelia |
| *Phacelia ivesiana* | Ives phacelia |
| *Plantago insularis* | woolly plantain |
| *Plantago patagonica* | plantain |
| *Salsola iberica* | Russian thistle |
| *Schismus barbatus* | Mediterranean grass |
| *Sphaeralcea ambigua* | desert mallow |
| *Sporobolus flexuosus* | mesa dropseed |
| *Stephanomeria exigua* | wire lettuce |
| *Stipa hymenoides* | indian ricegrass |
| *Streptanthella longirostris* | long-beaked twist-flower |
| *Stylocline micropoides* | desert nest-straw |
| *Thysanocarpus curvipes* | fringe-pod |
| *Tridens muticus* | slim tridens |
| *Yucca utahensis* | Utah yucca |

Appendix XV B. Alphabetical list of all diet plants at the Littlefield Site. 1990 through 1992.

| **Latin Name** | **Common Name** |
|---|---|
| *Ambrosia dumosa* | bursage |
| *Astragalus nuttallii* | |
| *Bromus rubens* | red brome |
| *Ceratoides lanata* | winter fat |
| *Chorizanthe rigida* | rigid spine-flower |
| *Cryptantha micrantha* | due cryptanth |
| *Cryptantha nevadensis* | Nevada cryptanth |
| *Ephedra nevadensis* | Nevada ephedra |
| *Eriogonum thomasii* | Thomas' eriogonum |
| *Erioneuron pulchellum* | fluffgrass |
| *Erodium cicutarium* | filaree |
| *Euphorbia parryi* | Parry spurge |
| *Festuca octoflora* | six-weeks fescue |
| *Glyptopleura setulosa* | Keysia |
| *Hilaria rigida* | big galleta |
| *Krameria parvifolia* | range ratany |
| *Langloisia setosissima* | bristly gilia |
| *Lepidium flavum* | yellow mustard-grass |
| *Lesquerella tennella* | slender bladderpod |
| *Lotus plebeius* | slender-bracted trefoil |
| *Mirabilis sp.* | |
| *Monoptilon bellioides* | Mojave desert star |
| *Oenethera primaverus* | evening primrose |
| *Pectocarya recurvata* | bent combseed |
| *Phacelia ivesianna* | Ives phacelia |
| *Plantago insularis* | woolly plantain |
| *Plantago patagonica* | plantain |
| *Rafinesquia neomexicana* | desert chicory |
| *Schismus barbatus* | Mediterranean grass |
| *Sphaeralcea ambigua* | desert mallow |
| *Stephanomeria pauciflora* | wire lettuce |
| *Stipa hymenoides* | indian ricegrass |
| *Strepthanthella longirostris* | long-beaked twist-flower |

Appendix XVI. Calculations of mean alpha preference values for diet selection in desert tortoises in 1990 - 1992 at the City Creek Site (A - C) and, the Littlefield Site (D - F). Plant species that were included were in greater than 1% of bites and greater than 1% of their relative occurrence on vegetation quadrats during all years in which data were available for each site individually.

Appendix XVI A. Calculations of mean alpha preference values for diet selection in desert tortoises at the City Creek Site in 1990 using food plant species that appeared > 1% of bites and relative occurrence on vegetation quadrats in 1990 - 1992.

| Tortoise | *Bromus spp.** | *Schismus barbatus* | *Erodium cicutarium* | *Cryptantha micrantha* | *Cryptantha spp.** |
|---|---|---|---|---|---|
| 393 | 0.453 | 0.000 | 0.657 | 0.623 | 0.000 |
| 1150 | 0.517 | 0.000 | 0.000 | 0.909 | 0.000 |
| 1190 | 0.435 | 0.360 | 0.000 | 0.807 | 0.278 |
| 1198 | 0.589 | 0.000 | 0.152 | 0.251 | 0.782 |
| 1208 | 1.253 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1244 | 0.431 | 0.000 | 0.161 | 0.347 | 0.856 |
| 1281 | 0.380 | 0.360 | 0.416 | 0.647 | 0.385 |
| 1282 | 0.775 | 0.158 | 0.342 | 0.400 | 0.367 |
| | | | | | |
| Mean Alpha | 0.604 | 0.110 | 0.216 | 0.498 | 0.333 |
| Standard Dev. | 0.290 | 0.164 | 0.238 | 0.303 | 0.341 |
| SD/(N)^.5 | 0.103 | 0.058 | 0.084 | 0.107 | 0.121 |
| Total mean Alpha | 0.352 | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVI B. Calculations of mean alpha preference values for diet selection in desert tortoises at the City Creek Site in 1991 using food plant species that appeared > 1% of bites and relative occurrence on vegetation quadrats in 1990 - 1992.

| Tortoise | *Schismus barbatus* | *Bromus spp.** | *Erodium cicutarium* | *Cryptantha micrantha* | *Cryptantha spp.** |
|---|---|---|---|---|---|
| 378 | 1.571 | 0.000 | 0.000 | 0.000 | 0.000 |
| 393 | 0.000 | 0.389 | 0.889 | 0.420 | 0.299 |
| 462 | 0.748 | 0.598 | 0.489 | 0.000 | 0.000 |
| 463 | 0.677 | 0.641 | 0.524 | 0.000 | 0.000 |
| 1144 | 0.270 | 0.806 | 0.693 | 0.000 | 0.000 |
| 150 | 0.268 | 0.333 | 0.993 | 0.276 | 0.221 |
| 1155 | 0.549 | 0.360 | 0.674 | 0.481 | 0.000 |
| 1208 | 0.451 | 0.429 | 0.439 | 0.579 | 0.407 |
| 1216 | 0.000 | 0.774 | 0.796 | 0.000 | 0.000 |
| 1234 | 0.454 | 0.268 | 0.000 | 0.769 | 0.528 |
| 1244 | 0.000 | 0.526 | 1.045 | 0.000 | 0.000 |
| 1281 | 0.000 | 0.000 | 0.970 | 0.601 | 0.000 |
| 1282 | 0.305 | 0.274 | 0.451 | 0.818 | 0.346 |
| | | | | | |
| mean | 0.407 | 0.415 | 0.613 | 0.303 | 0.139 |
| SD | 0.272 | 0.231 | 0.302 | 0.323 | 0.198 |
| SD/(N)^.5 | 0.073 | 0.062 | 0.081 | 0.086 | 0.053 |
| TTL Mean Alpha | 0.378 | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVI C. Calculations of mean alpha preference values for diet selection in desert tortoises at the City Creek Site in 1992 using food plant species that appeared > 1% of bites and relative occurrence on vegetation quadrats in 1990 - 1992.

| Tortoise | *Bromus spp.** | *Erodium cicutarium* | *Cryptantha micrantha* | *Schismus barbatus* | *Cryptantha spp.** |
|---|---|---|---|---|---|
| 393 | 0.119 | 0.000 | 1.094 | 0.000 | 0.460 |
| 466 | 0.000 | 1.571 | 0.000 | 0.000 | 0.000 |
| 592 | 0.000 | 1.571 | 0.000 | 0.000 | 0.000 |
| 1117 | 0.270 | 0.788 | 0.000 | 0.534 | 0.420 |
| 1126 | 0.391 | 0.589 | 0.142 | 0.802 | 0.100 |
| 1130 | 0.000 | 0.658 | 0.000 | 0.913 | 0.000 |
| 1144 | 0.252 | 1.319 | 0.000 | 0.000 | 0.000 |
| 1150 | 0.292 | 0.716 | 0.448 | 0.495 | 0.272 |
| 1153 | 0.209 | 0.774 | 0.000 | 0.753 | 0.000 |
| 1190 | 0.276 | 0.391 | 0.987 | 0.000 | 0.296 |
| 1198 | 0.434 | 0.272 | 0.933 | 0.287 | 0.162 |
| 1208 | 0.168 | 0.527 | 0.779 | 0.281 | 0.395 |
| 1216 | 0.584 | 0.241 | 0.000 | 0.894 | 0.177 |
| 1231 | 0.000 | 0.658 | 0.000 | 0.913 | 0.000 |
| 1234 | 0.000 | 0.230 | 0.958 | 0.000 | 0.556 |
| 1244 | 0.204 | 0.375 | 0.000 | 1.092 | 0.191 |
| 1282 | 0.470 | 0.616 | 0.470 | 0.000 | 0.530 |
| | | | | | |
| mean | 0.216 | 0.665 | 0.342 | 0.410 | 0.209 |
| stdev | 0.183 | 0.451 | 0.434 | 0.411 | 0.202 |
| stdev/(N)^.5 | 0.044 | 0.109 | 0.105 | 0.100 | 0.049 |
| Total Mean Alpha | 0.368 | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVI D. Calculations of mean alpha preference values for diet selection in desert tortoises at the Littlefield Site in 1990 using food plant species that appeared > 1% of bites and relative occurrence on vegetation quadrats in 1990 - 1992.

| Tortoise | *Bromus spp.** | *Erodium cicutarium* | *Plantago spp.** | *Schismus barbatus* |
|---|---|---|---|---|
| 148.224 | 0.530 | 0.851 | 0.000 | 0.437 |
| 203 | 0.000 | 1.273 | 0.283 | 0.095 |
| 207 | 0.542 | 0.826 | 0.232 | 0.383 |
| 770 | 0.393 | 0.564 | 0.000 | 0.853 |
| HO37 | 0.571 | 1.000 | 0.000 | 0.000 |
| HO67 | 0.377 | 0.791 | 0.282 | 0.559 |
| HO84 | 0.694 | 0.000 | 0.000 | 0.877 |
| | | | | |
| mean | 0.444 | 0.758 | 0.114 | 0.458 |
| SD | 0.223 | 0.398 | 0.143 | 0.339 |
| SD/(N)^.5 | 0.084 | 0.150 | 0.054 | 0.128 |
| Total Mean Alpha | 0.443 | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVI E. Calculations of mean alpha preference values for diet selection in

Appendix XVI E. Calculations of mean alpha preference values for diet selection in desert tortoises at the Littlefield Site in 1991 using food plant species that appeared > 1% of bites and relative occurrence on vegetation quadrats in 1990 - 1992.

| Tortoise | *Schismus barbatus* | *Plantago spp.** | *Bromus spp.** | *Erodium cicutarium* |
|---|---|---|---|---|
| 207 | 0.000 | 0.619 | 0.000 | 0.951 |
| 210 | 0.777 | 0.526 | 0.529 | 0.000 |
| 280 | 0.375 | 0.428 | 0.142 | 0.964 |
| HO36 | 0.416 | 0.543 | 0.216 | 0.809 |
| HO67 | 0.308 | 0.499 | 0.194 | 0.929 |
| HO68 | 0.617 | 0.226 | 0.000 | 0.902 |
| HO84 | 0.305 | 0.744 | 0.000 | 0.736 |
| S156 | 0.386 | 0.551 | 0.145 | 0.849 |
| | | | | |
| Mean | 0.398 | 0.517 | 0.153 | 0.768 |
| SD | 0.177 | 0.156 | 0.178 | 0.336 |
| SD/(N)^.5 | 0.062 | 0.055 | 0.063 | 0.119 |
| Total Mean Alpha | 0.459 | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVI F. Calculations of mean alpha preference values for diet selection in desert tortoises at the Littlefield Site in 1992 using food plant species that appeared > 1% of bites and relative occurrence on vegetation quadrats in 1990 - 1992.

| Tortoise | *Bromus spp.** | *Schismus barbatus* | *Erodium cicutarium* | *Plantago spp.** |
|---|---|---|---|---|
| 1.285 | 0.000 | 0.736 | 0.704 | 0.370 |
| 207 | 0.000 | 0.000 | 0.000 | 1.571 |
| 210 | 0.000 | 0.000 | 0.000 | 1.571 |
| 250 | 0.000 | 0.755 | 0.673 | 0.385 |
| 280 | 0.000 | 0.794 | 0.582 | 0.448 |
| HO36 | 0.419 | 0.000 | 0.487 | 0.902 |
| HO42 | 0.000 | 0.854 | 0.454 | 0.511 |
| HO67 | 0.280 | 1.080 | 0.227 | 0.313 |
| HO68 | 0.138 | 1.117 | 0.398 | 0.154 |
| S108 | 0.290 | 0.633 | 0.415 | 0.690 |
| S131 | 0.000 | 0.977 | 0.480 | 0.321 |
| S153 | 0.000 | 0.000 | 1.062 | 0.509 |
| S156 | 0.116 | 0.904 | 0.583 | 0.261 |
| Mean | 0.096 | 0.604 | 0.467 | 0.616 |
| SD | 0.145 | 0.439 | 0.286 | 0.465 |
| SD/(N)^.5 | 0.040 | 0.122 | 0.079 | 0.129 |
| Total Mean Alph | 0.445 | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVII. Calculations for alpha preference values calculated for desert tortoises at the City Creek Site (A-B) and, the Littlefield Site (C-D). Plant species were those that appeared in the diets in greater that 1% of bites and greater than 1 % of the frequency occurrence on vegetation transects for single years.

Appendix XVII A. Calculations for alpha preference values calculated for desert tortoises at the City Creek Site using food plant species that appeared in the diets in 1991 and had > 1% of bites and frequency occurrence on vegetation transects.

| Tortoise | *Schismus barbatus* | *Bromus spp.** | *Plantago spp.** | *Eriophyllum wallacei* | *Erodium cicutarium* | *Cryptantha micrantha* | *Descurainia pinnata* | *Gilia spp.** | *Cryptantha spp.** |
|---|---|---|---|---|---|---|---|---|---|
| 378 | 0.349 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.222 | 0.000 | 0.000 |
| 393 | 0.000 | 0.285 | 0.230 | 0.000 | 0.614 | 0.306 | 0.000 | 0.682 | 0.221 |
| 462 | 0.566 | 0.460 | 0.000 | 0.000 | 0.379 | 0.000 | 0.439 | 0.460 | 0.000 |
| 463 | 0.582 | 0.553 | 0.306 | 0.000 | 0.454 | 0.000 | 0.000 | 0.381 | 0.000 |
| 1144 | 0.216 | 0.620 | 0.000 | 0.000 | 0.541 | 0.000 | 0.633 | 0.000 | 0.000 |
| 1150 | 0.247 | 0.306 | 0.135 | 0.312 | 0.883 | 0.254 | 0.196 | 0.000 | 0.204 |
| 1155 | 0.407 | 0.272 | 0.000 | 0.360 | 0.494 | 0.360 | 0.576 | 0.000 | 0.000 |
| 1198 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.571 | 0.000 | 0.000 |
| 1208 | 0.127 | 0.123 | 0.149 | 0.000 | 0.123 | 0.159 | 1.203 | 0.149 | 0.114 |
| 1216 | 0.000 | 0.414 | 0.000 | 0.000 | 0.424 | 0.000 | 0.958 | 0.000 | 0.000 |
| 1234 | 0.310 | 0.185 | 0.185 | 0.000 | 0.000 | 0.506 | 0.610 | 0.402 | 0.358 |
| 1244 | 0.000 | 0.379 | 0.323 | 0.351 | 0.690 | 0.000 | 0.000 | 0.511 | 0.000 |
| 1281 | 0.000 | 0.000 | 0.287 | 0.383 | 0.577 | 0.383 | 0.559 | 0.250 | 0.000 |
| 1282 | 0.270 | 0.241 | 0.145 | 0.226 | 0.398 | 0.706 | 0.382 | 0.000 | 0.306 |
| | | | | | | | | | |
| mean | 0.220 | 0.274 | 0.126 | 0.117 | 0.398 | 0.191 | 0.596 | 0.202 | 0.086 |
| sd | 0.208 | 0.200 | 0.126 | 0.166 | 0.275 | 0.233 | 0.492 | 0.241 | 0.131 |
| sd/(N)^.5 | 0.056 | 0.054 | 0.034 | 0.044 | 0.074 | 0.062 | 0.131 | 0.064 | 0.035 |
| Total Mean Alpha | 0.246 | | | | | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVII B. Calculations for alpha preference values calculated for desert tortoises at the City Creek Site using food plant species that appeared in the diets in 1992 and had > 1% of bites and frequency occurrence on vegetation transects.

| Tortoise | *Bromus spp.** | *Festuca octoflora* | *Erodium cicutarium* | *Cryptantha micrantha* | *Eriophyllum wallacei* | *Streptanthella longirostris* | *Gilia spp.** | *Schismus barbatus* | *Stephanomeria exigua* | *Lepidium flavum* | *Cryptantha spp.** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 393 | 0.063 | 0.000 | 0.000 | 0.489 | 0.000 | 0.000 | 0.532 | 0.000 | 0.748 | 0.000 | 0.237 |
| 466 | 0.000 | 0.239 | 1.332 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 592 | 0.000 | 0.232 | 0.364 | 0.000 | 1.133 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1117 | 0.250 | 0.239 | 0.717 | 0.000 | 0.298 | 0.000 | 0.000 | 0.492 | 0.000 | 0.000 | 0.388 |
| 1126 | 0.344 | 0.363 | 0.515 | 0.123 | 0.138 | 0.000 | 0.000 | 0.693 | 0.165 | 0.204 | 0.090 |
| 1130 | 0.000 | 0.000 | 0.581 | 0.000 | 0.457 | 0.000 | 0.000 | 0.789 | 0.000 | 0.000 | 0.000 |
| 1144 | 0.243 | 0.000 | 1.202 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.272 | 0.000 | 0.000 |
| 1150 | 0.283 | 0.000 | 0.693 | 0.436 | 0.183 | 0.145 | 0.000 | 0.481 | 0.000 | 0.000 | 0.264 |
| 1153 | 0.135 | 0.000 | 0.475 | 0.000 | 0.503 | 0.000 | 0.000 | 0.464 | 0.623 | 0.000 | 0.000 |
| 1190 | 0.165 | 0.221 | 0.232 | 0.527 | 0.298 | 0.395 | 0.285 | 0.000 | 0.553 | 0.000 | 0.177 |
| 1198 | 0.296 | 0.100 | 0.188 | 0.593 | 0.000 | 0.000 | 0.726 | 0.199 | 0.000 | 0.260 | 0.110 |
| 1208 | 0.090 | 0.168 | 0.272 | 0.386 | 0.228 | 0.183 | 0.000 | 0.149 | 0.887 | 0.000 | 0.209 |
| 1216 | 0.542 | 0.119 | 0.226 | 0.000 | 0.000 | 0.206 | 0.268 | 0.816 | 0.000 | 0.000 | 0.165 |
| 1231 | 0.000 | 0.000 | 0.658 | 0.000 | 0.000 | 0.000 | 0.000 | 0.913 | 0.000 | 0.000 | 0.000 |
| 1234 | 0.000 | 0.078 | 0.123 | 0.455 | 0.000 | 0.159 | 0.000 | 0.000 | 0.971 | 0.000 | 0.287 |
| 1244 | 0.194 | 0.000 | 0.355 | 0.000 | 0.000 | 0.323 | 0.000 | 1.001 | 0.000 | 0.000 | 0.180 |
| 1282 | 0.256 | 0.000 | 0.328 | 0.256 | 0.281 | 0.000 | 0.487 | 0.000 | 0.679 | 0.000 | 0.287 |
| | | | | | | | | | | | |
| mean | 0.168 | 0.103 | 0.486 | 0.192 | 0.207 | 0.083 | 0.135 | 0.353 | 0.288 | 0.027 | 0.141 |
| sd | 0.157 | 0.119 | 0.347 | 0.227 | 0.298 | 0.131 | 0.219 | 0.375 | 0.357 | 0.080 | 0.129 |
| sd/(N)^.5 | 0.038 | 0.029 | 0.084 | 0.055 | 0.072 | 0.032 | 0.053 | 0.091 | 0.087 | 0.019 | 0.031 |
| Total Mean Alpha | | 0.199 | | | | | | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVII C. Calculations for alpha preference values calculated for desert tortoises at the Littlefield Site using food plant species that appeared in the diets in 1991 and had > 1% of bites and frequency occurrence on vegetation transects.

| Tortoise | *Schismus barbatus* | *Plantago spp.** | *Lepidium flavum* | *Erodium cicutarium* | *Monoptilon bellioides* | *Eriogonum thomassii* | *Bromus spp.** | *Lesquerella tenella* |
|---|---|---|---|---|---|---|---|---|
| 207 | 0.000 | 0.606 | 0.000 | 0.459 | 0.765 | 0.000 | 0.000 | 0.000 |
| 210 | 0.258 | 0.180 | 0.174 | 0.000 | 0.000 | 0.119 | 0.211 | 1.127 |
| 280 | 0.487 | 0.544 | 0.393 | 0.606 | 0.000 | 0.000 | 0.206 | 0.000 |
| HO36 | 0.317 | 0.400 | 0.910 | 0.308 | 0.000 | 0.000 | 0.191 | 0.000 |
| HO67 | 0.264 | 0.413 | 0.188 | 0.382 | 0.325 | 0.469 | 0.188 | 0.529 |
| HO68 | 0.773 | 0.266 | 0.301 | 0.540 | 0.000 | 0.000 | 0.000 | 0.306 |
| HO84 | 0.378 | 0.952 | 0.000 | 0.464 | 0.000 | 0.000 | 0.000 | 0.000 |
| S156 | 0.343 | 0.474 | 0.624 | 0.370 | 0.171 | 0.000 | 0.149 | 0.407 |
| Mean | 0.352 | 0.479 | 0.324 | 0.391 | 0.158 | 0.073 | 0.118 | 0.296 |
| SD | 0.181 | 0.249 | 0.308 | 0.197 | 0.129 | 0.175 | 0.094 | 0.410 |
| SD/(N)^.5 | 0.064 | 0.088 | 0.109 | 0.070 | 0.046 | 0.062 | 0.033 | 0.145 |
| Total Mean Alpha | | 0.274 | | | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

Appendix XVII D. Calculations for alpha preference values calculated for desert tortoises at the Littlefield Site using food plant species that appeared in the diets in 1992 and had > 1% of bites and frequency occurrence on vegetation transects.

| Tortoise | *Schismus barbatus* | *Bromus spp.* * | *Erodium cicutarium* | *Lepidium flavum* | *Plantago spp.** |
|---|---|---|---|---|---|
| 1.285 | 0.735 | 0.000 | 0.704 | 0.000 | 0.370 |
| 207 | 0.698 | 0.000 | 0.624 | 0.357 | 0.360 |
| 210 | 0.795 | 0.000 | 0.582 | 0.000 | 0.448 |
| 250 | 0.000 | 0.418 | 0.487 | 0.000 | 0.901 |
| 280 | 0.650 | 0.000 | 0.360 | 0.638 | 0.405 |
| HO36 | 1.080 | 0.281 | 0.228 | 0.000 | 0.313 |
| HO42 | 0.986 | 0.127 | 0.367 | 0.382 | 0.142 |
| HO67 | 0.633 | 0.290 | 0.416 | 0.000 | 0.691 |
| HO68 | 0.977 | 0.000 | 0.480 | 0.000 | 0.322 |
| S108 | 0.859 | 0.114 | 0.559 | 0.270 | 0.252 |
| S131 | 0.000 | 0.000 | 0.000 | 0.000 | 1.571 |
| S153 | 0.000 | 0.000 | 0.000 | 0.000 | 1.571 |
| S156 | 0.000 | 0.000 | 1.061 | 0.000 | 0.510 |
| Mean | 0.570 | 0.095 | 0.451 | 0.127 | 0.604 |
| SD | 0.417 | 0.145 | 0.284 | 0.213 | 0.470 |
| SD/(N)^5 | 0.116 | 0.040 | 0.079 | 0.059 | 0.130 |
| Total Mean Alpha | 0.369 | | | | |

* Cryptantha spp = C. angustifolia, C. nevadensis
Bromus spp. = B. tectorum, and B. rubens
Plantago spp. = P. insularis, and P. patagonica
Gilia spp. = G. scopulorum, and G. leptomeria

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